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VOL. 14 AUGUST, 1925 No. 2

BRASS AND COPPER FOR WATER SERVICE AND PLUMBING PIPE[1]

BY WM. G. SCHNEIDER[2]

Nowadays every farseeing user of pipe for domestic water purposes should have certain definite points in mind when in the market for his requirements. These points are:

1. Will the pipe affect the water so that its appearance makes its use repugnant?
2. Will the pipe corrode rapidly?
3. Is the pipe easily installed?
4. Is the pipe economical?

In practically every instance where domestic water piping is concerned, irrespective, within certain limits, of whether the pipe is used as water main, service pipe or plumbing pipe, these points should be considered by the prospective user, whether he be an architect, sanitary expert, water works man, plumber, contractor or a builder of a home, an apartment, hospital, school or industrial construction.

Pipes of copper are the oldest pipes we know. The fact that we not only know of such pipes, but actually have them, is the most wonderful testimonial in the world of copper's enduring properties.

[1] Presented before the New York Section meeting, March 26, 1925.

[2] Research Department, Copper and Brass Research Association, New York, N. Y.

A piece of copper pipe, 5400 years old, is on display at the office of the Copper and Brass Research Association. The pipe was unearthed at Ghizeh, near the tomb of the Egyptian King Sahoure, and is believed by Egyptologists to be 5400 years old. Looking at this piece of copper pipe one is tempted to say that the world has been nodding for these many centuries—because it is only today reawakening to the advantages of using copper and brass for piping. Brass, a copper alloy, has been used for many years for pipe. The Parker House, Boston, erected in 1856 has brass pipe that has given 67 years of service without a leak. The use of brass for water piping is just coming into its own because those vitally interested in its use are more and more coming to appreciate its value.

As our knowledge of the various problems relating to conveying domestic water has increased we have also progressed step by step from the open trough to the wooden pipe, lead pipe, genuine wrought iron and steel pipe, until now those of us who understand the problem use those materials—brass and copper—which we know are the best suited to the purpose.

The use of brass and copper for water service piping has just started within our own times and it is because you wish to know how these materials are serving that the foregoing facts are brought out. They present the picture of conveying water through piping, but in the case of services do not touch on the exterior conditions that such piping must meet. The exterior corrosion of piping, due to the soil in which it is embedded, is in many instances even more important from the standpoint of the life of the service pipe than the effect of water passing through the material.

Probably the Lake Superior Region of Northern Michigan is Nature's great testing laboratory. It is here that the two metals which enter our lives most abundantly—copper and iron—were tested by air, by water and by the soil. The test has been underway for not one year or five years, but for thousands of years. This test in itself shows that it is not possible for iron, such as is used for plumbing pipe, to exist where it is in contact with water or air or soil that contains the least moisture. Copper, on the other hand, was deposited in Nature's laboratory as pure metal and it is being extracted today, after being subjected for thousands of years to the action of water, air and soil, in just as good a condition as when Nature deposited it as pure native copper.

Probably everybody has, at one time or another, turned on the faucet and seen a stream of dirty red rust-colored water issue therefrom. This red water nuisance is due entirely to the use of ferrous or corrodible pipe or other ferrous products, such as tanks, etc. This rust is sure to stain expensive white enamel fixtures, possibly on wash day ruin the clothes, not to mention the temper of the housewife. Red rust is iron oxide and is certain to form wherever iron such as is used for piping is exposed to water and air. Brass or copper pipe avoid the red rusty water nuisance and while the comfort and convenience, as well as the sanitary aspect of their use on this account, are hard to measure in dollars and cents, it is nevertheless real and should not be overlooked.

The question of corrosion has been here separated from the foregoing as it is desired to discuss it as it relates to the life of plumbing and service pipe. With a service pipe material the question of corrosion is twofold, as stated heretofore—we have not only the corrosive influence of the water on the interior of the pipe, but in addition in certain localities soil corrosion on the exterior of the pipe. Undoubtedly every one interested in this subject has seen an iron pipe completely clogged with rust or so badly clogged that not more than 10 per cent of its effective area was available for conveying water. This rust clogging is an example of corrosion. Wherever iron is used for drawn or welded piping and corrosive water conditions exist, as they do in most localities, rust is formed. A 1-inch iron pipe is completely rust clogged when one-fortieth of its wall thickness is converted into rust. The clogging with rust of service and plumbing pipe is a common occurrence, and is noticed by the reduced flow of water at faucets or in the burning out of water coils in heaters. This rust clogging is more prevalent in hot water pipes than in cold. Plumbing contractors always make an allowance for rust clogging by using larger sizes than are actually required. Inasmuch as brass or copper do not rust and do not become rust clogged, it is possible to use a smaller sized pipe as compared to the necessary size of pipes that rust. These comparative sizes are as follows:

In hot water lines

½-inch brass pipe will do the work of ¾-inch iron
½-inch brass pipe will do the work of 1 -inch iron
¾-inch brass pipe will do the work of 1¼-inch iron
1 -inch brass pipe will do the work of 1½-inch iron

1½-inch brass pipe will do the work of 2½-inch iron
2 -inch brass pipe will do the work of 3 -inch iron

In cold water lines

½-inch brass pipe will do the work of ¾-inch iron
¾-inch brass pipe will do the work of 1 -inch iron
1 -inch brass pipe will do the work of 1¼-inch iron
1¼-inch brass pipe will do the work of 1½-inch iron
1½-inch brass pipe will do the work of 2 -inch iron
2 -inch brass pipe will do the work of 2½-inch iron

In branch lines, both hot and cold, ⅜-inch brass pipe will do the work of ½-inch iron.

There have been volumes written on "corrosion" and the "theory of corrosion," and there is no intention to discuss the highly technical side of this subject in this address. For practical purposes it is well to remember that every theory of corrosion and every expert on this subject admits that, of all materials used for plumbing pipe that are suitable the country over, none is as little corroded as brass or copper. In other words, under the same general water service conditions the country over, which is the subject of immediate concern to us in this address, brass or copper as piping is the best possible material which is available to us today to resist corrosion.

Without doubt the easiest method generally used today of connecting pipe is by threaded fittings. Wiped joints nowadays mean a high labor cost and skilled help. Special joints with a breakable material are as a rule difficult to make and to maintain. Brass pipe enjoys an advantage over copper in this respect as it is easier to thread. In fact it is just as easy for a good workman to install brass as galvanized pipe. The same dies that thread the galvanized pipe may be used for threading brass pipe.

The following ten simple rules are the practice of good plumbers and may at some time or other be of help to you, i.e.:

1. Use only good brass fittings with threads of standard gauge and size. Do not use iron fittings on a brass pipe job.
2. Cut the pipe with your regular cutters or with a hack saw. Ream the pipe to remove all burrs.
3. Use good dies without broken teeth.
4. One-quarter of an inch per 10 feet of length is ample allowance for expansion for hot and cold water lines.
5. When threading keep the pipe as near to the vise as is consistent with easy working.

6. While a lubricant is not absolutely necessary, it facilitates threading.

7. With properly made dies run the die onto the pipe until its surface is just flush with the pipe. When such threaded pipe is screwed home in the fitting no threads will show.

8. Use care in threading and cut the threads down to exactly standard gauge and size.

9. Best appearance in the finished job is obtained by using friction jaws in the vise and friction wrenches. Use care if you screw brass pipe home with a stillson wrench so as not to mar it unduly.

10. With careful threading, good fittings and proper screwing home no pipe "dope" is necessary. Wicking is recommended as preferable to a paste of ground red lead and glycerine, or red lead and linseed oil.

It was probably noticed that the fourth item at the beginning of this address referred to "economy" and not to cost. The reason for this is self-evident when one considers replacement expenses made necessary in a few years when corrodible piping is used.

The price, as published, of various piping materials is as follows:

	Standard pipe sizes, cents per foot
1-inch galvanized steel	10½
1-inch genuine wrought iron	14¾
1-inch galvanized genuine wrought iron	18¼
1-inch brass pipe	40
1-inch copper pipe	44½
1-inch lead pipe (1A—4 pounds per foot)	48

but inasmuch as corrodible pipe materials soon become badly coated with rust and rust clogged, it is necessary to use a larger size of pipe. Equating the prices accordingly, we have

	Standard pipe sizes, cents per foot
1¼-inch galvanized steel	14
1¼-inch genuine wrought iron	20
1¼-inch galvanized genuine wrought iron	25
1-inch brass	40
1-inch copper	44½
1-inch lead (1A—4 pounds per foot)	48

The total cost of any installation is made up of material, labor and fixed charges. As far as installations of plumbing or service pipe is concerned the cost of the pipe is a minor item as compared to all other charges. The labor charge on the other hand is large compared to the cost of the pipe. On this basis alone we should select the very best pipe obtainable, provided it is possible to install it on a basis comparable with the cost of installing an inferior pipe.

Of the materials listed above, lead is the most costly to install and requires more or less skilled labor. Brass and copper have all of the advantages of lead and none of its disadvantages.

Brass and copper are as easily installed, with the identical tools, as steel or iron pipe. Under the same conditions they will outlast corrodible pipe many times over. How long brass or copper will last cannot definitely be stated, but plumbing installations made in 1865—sixty years ago—are still going strong. If we assume a service pipe installation of 50 feet where the charges, excluding the pipe and connection to main, are $1.50 per foot (this may vary according to best advice, from 75 cents to $4.00) we arrive at the following:

	GALVANIZED STEEL	BLACK GENUINE WROUGHT IRON	GALVANIZED GENUINE WROUGHT IRON	BRASS	COPPER	LEAD
Pipe	7.00	10.00	12.50	20.00	22.25	24.00
Labor and other charges	75.00	75.00	75.00	75.00	75.00	75.00
	82.00	85.00	87.00	95.00	97.25	99.00

With only one replacement cost at the end of say, five years in the case of corrodible pipe, the economy of brass or copper is apparent. There exist also fundamental reasons why brass or copper are the materials for plumbing or service piping. As compared to any and all pipes, brass and copper have the following advantages:

1. Minimum of corrosion
   a. No rusty water
   b. No rust clogging
2. As easily installed as any other piping
3. Are the cheapest and best in the end.

Speaking specifically of service pipe, brass and copper have the foregoing advantages, and in addition:

1. It is possible to eliminate the lead gooseneck by using soft pipe that may be bent to the main
2. No replacing, necessitating the tearing up of expensive pavement as with corrodible piping
3. No inconveniences, as
   a. inadequate water supply
   b. shutting off water for repairs and replacements.
4. No loss of water due to leaks or broken pipes

There are thousands of installations of brass pipe plumbing giving entire satisfaction. Brass and copper for service pipe material are just coming into their own. Heretofore water companies in the State of Pennsylvania were not much concerned with what kind of services were installed by the house owner. The Public Service Commission of this State has ruled, however, that the pipes of the water company end at the curb box, with the result that progressive water companies have been quick to see the advantages of installing copper and brass, and are now standardizing on such installations. They appreciate that the best piping materials—brass and copper—which deliver clean, clear, rust-free water, are non-corrodible and easily installed, are the most economical in the end.

DISCUSSION

THOMAS ANDERSON: I would like to ask Mr. Schneider a question. You have spoken considerably of brass and copper. Just what do you mean, Mr. Schneider? In regard to the copper installation, have you reference to the thin copper tubing or copper piping?

W. G. SCHNEIDER:[2] Either one. I was speaking of the material. The city of Scranton, Pa., has adopted standard pipe size copper pipe exclusively for its water service piping.

With regard to the tubing, it is too recent an innovation and has not yet absolutely demonstrated its worth under many varying conditions. It enjoys a great advantage from the standpoint of cost and probably will be extensively used if it proves satisfactory.

When installing "standard pipe size" pipe, standard threads are cut and fittings used. When installing copper tubing, which has a thin wall and does not permit of cutting standard threads, it is necessary to use special fittings, which are so constructed as to eliminate all threading of the tubing. A steel expanding tool is used which quickly and easily gives the tubing a flared or "bell shape." The construction of the connecting fitting or union is such that, when tightened, it firmly and tightly squeezes the metal of the tube between the male and female part of the fitting. The fitting is so made that the female half fits around the tube and supports the outside of flare on the tube, while the male part tends to go inside

of the tube and squeeze the metal of the tube between it and the supporting female half. Such fittings as these or variations of them are now being regularly used for connecting copper tubing in England that is being installed for plumbing purposes.

A. M. JOHNSTONE:[3] Might I ask if they have any data as to the relative life and performance of cement lined pipe adequately covered on the outside to prevent corrosion?

W. G. SCHNEIDER:[2] I have no data at the moment to offer on that subject. I think most of the trouble with cement lined pipe has been at the joints. It is difficult to maintain the joints in the case of cement pipe after it is installed; a certain amount of rusting takes place.

F. T. KEMBLE:[4] I should like to ask Mr. Schneider two questions in connection with this. The first was as to deteoriation of copper pipe in the ground as compared to brass pipe. I have always understood that where you ground electrical lines on a plate the purer the copper the worse the condition you found it in. Maybe I am wrong. Now the other question I wanted to ask was in regard to pressure that brass pipe had withstood; take 2-inch or larger, and at a pressure of say, 100 pounds.

W. G. SCHNEIDER:[2] Nowadays good brass pipe, standard pipe size, is tested under a pressure of 1000 pounds per square inch before it leaves the mill. Two-inch brass pipe, standard pipe size, may safely be used against a working pressure of about 500 pounds, at which pressure the safety factor would be six. Heavy grounds, stray currents and other electrical phenomena involve so many variable factors that no one can say for a certainty just what will take place. It is advisable to avoid such conditions and make every effort to prevent them from occurring, not only when using copper or brass pipe, but also when using pipe of any other material or metal.

N. C. NICOL:[5] After all is said, the kind of pipe used for water services will depend upon the ultimate cost over a period of years.

[3] Sanitary and Hydraulic Engineer, New York, N. Y.
[4] Secretary, New Rochelle Water Company, New Rochelle, N. Y.
[5] Field Engineer, National Tube Company, Pittsburgh, Pa.

If a more expensive material than steel is used, the interest charges on the extra investment must be less than the cost of repairs on the steel pipe in order to justify the greater initial expense. As a specific example to illustrate this, consider an installation where the cost of the pipe would be $100 for galvanized steel pipe as compared with $350 for brass pipe. The carrying charges on the additional $250 at 6 per cent would amount to $15 per year, and this compounded over a period of years prior to any failures in the steel pipe, which might or might not fail before the brass, would be in a great majority of cases, more than sufficient to take care of the repairs.

As to just what the life of steel pipe is underground carrying cold water, there is no definite answer, as this depends upon local water and soil conditions. We do know, however, that we have a great many installations now in active service after a period of thirty years or more. The action of cold water on pipe is not ordinarily severe, and the waters which attack steel pipe to any appreciable extent are decidedly in the minority.

When a bad water is encountered this seems to show little regard for the kind of pipe material used and brass pipe is not a cure-all by any means for pipe trouble due to corrosive water—viz.:

We understand that considerable trouble was experienced with brass pipe which was installed in the water service lines in East Providence, R. I. This pipe had been in a comparatively few years, and a great deal of it had to be removed on account of its breaking at the joints.

Only a short time ago I examined a piece of brass pipe removed from a mill in Passaic, N. J., carrying cold water, which failed in a similar manner after eight years' service.

We had occasion to investigate the pipe used for hot salt water supplies in the Altantic City Hotels, and found that, under these conditions, brass and copper pipe lasted less than seven years.

Condenser tubes using salt or brackish water in condensers, where Admiralty metal tubes are used, have a surprisingly short life, amounting to only two to three years in many cases. Failure of brass pipe in the hot water supply lines of the William Penn Hotel and other buildings in Pittsburgh, and the failure of brass valves in the hot water supplies of a number of hotels, certainly would not lead us to believe that brass is by any means non-destructible.

Wherever a water is encountered which is destructive in a high degree to pipe material, a solution to this problem would be a centralized plant for treating the entire water supply in order to render it non-corrosive. The causes of corrosion are well known today, and it is recognized that oxygen in any form is responsible for most of the corrosion in water, where the water is at a normal temperature or heated. Of course, the action is very much more rapid and more noticeable at the higher temperature. The removal of the dissolved oxygen may be accomplished by deaeration. The hydrogen ion concentration and tendency to form protective coatings on the metal are also important. Proper treatment of the water would seem to be the logical way of handling the matter, and thus protection would be given not only to the mains and service pipes, but also to the water supply pipes throughout the city buildings.

W. G. SCHNEIDER:[2] Mr. French has just asked me if I have any answer that I would like to make with regard to the question of corrosion and the question of the life of brass pipe Admiralty condenser tubes.

Admiralty condenser tubes (70 per cent copper, 29 per cent zinc, 1 per cent tin) are regularly specified by the Government and by other engineers for handling salt water and are today the best tubes which are available for resisting the corrosion conditions for which these tubes are used. Just recently tests have shown that tubes of 80 per cent copper and 20 per cent zinc are also highly resistant to corrosion in salt water. In and around New York Harbor where the water is very badly polluted and where probably the worst condenser tube conditions are met with Admiralty tubes last about twice as long (eight to ten years) as mentioned by the previous speaker.

As regards the life of plumbing pipe, I recall at the moment a survey that was made by a manufacturer of genuine wrought iron pipe. The City of Pittsburgh has water that is very severe on piping. This survey took into account 128 apartment houses located in Pittsburgh. It shows that at the end of four years trouble started on installations with steel pipe and that at the end of eleven years every installation (28 in number) of steel pipe had failed. In the case of sixty six installations of genuine wrought iron pipe, failures started at about the eighth year and at the end of eighteen years the sixty six genuine wrought iron pipe installations had failed except one. With brass pipe, the bulletin states that at the end of eighteen years

no single failure of the thirty four brass pipe installations had been recorded. I think this answers the question as to corrosion.

J. W. ACKERMAN:[6] The place where I live, Watertown, N. Y., at the present time has a very peculiar water supply. It comes from the feeding swamps of the Adirondacks and also, as some of you know, is in the pulp mill district. A large amount of sulfite waste is dumped into the Black River from which the supply is obtained. That, with the solution, its very high color and its very low alkalinity, sometimes makes it a very difficult water to treat. Mr. Allen Hazen has made the statement that he thinks it is the most difficult water with which he has ever come in contact.

After the installation of the filtering plant they experienced the same trouble, as they do all over the country whenever they make a change in their supply—that is, they began to have very serious red water troubles. They have tried almost everything. An aeration plant is in operation there. It takes out some of the CO_2. At certain seasons of the year we have to add alkali. Yet we continue to have red water troubles.

We have resorted to cement lined piping. I am going to try the copper tubing, but for hot water pipes everybody concedes that they will not last at all. The brass hot water pipes do not last long either. Whether or not the copper tubing will is something which we would like to try out.

There is only one suggestion that I have—one criticism I have to offer on the paper, I think Mr. Schneider put a rather high cost upon the labor charge of installation of service lines, because I know we charge $25 and $30 for the installation of $\frac{3}{4}$- and 1-inch pipe. So your prices for labor, which would materially alter your per cent, I think are a little high.

W. G. SCHNEIDER:[2] I tried to make clear in my paper that the "cost of labor and other charges" as given, was really a relative matter, because what I did there was to take the cost of the various piping materials and then charge the same labor for installing each of them. So that, if the prices are high, it is an error in the assumed figure and does not favor or discriminate against any material.

I made a note in my paper that the installation charge, according to best advice given me, would vary anywhere from 75 cents to

[6] City Manager, Watertown, N. Y.

$4.00 a foot; an average figure of $1.50 a foot was assumed to cover the cost of paving, and so forth. Undoubtedly there are many localities where you can install service pipe for 75 or 50 cents, or even less than this. The figure is relative. It applies to the cost of installing every material.

The water conditions of your locality are exceptional and are due as you say to discharge of liquors from pulp and paper mills. It should be borne in mind that no pipe material today will resist permanently such severe corrosion conditions and the only alternative is to use the material that will last the longest. It is my general observation that, under the same service conditions, a proper installation of brass or copper pipe will outlast an iron or steel pipe installation many times over when used for conveying domestic water. I would be very glad to take the matter up with you and discuss it further. Possibly you are not using the best kind of piping for your conditions.

A. T. CLARK:[7] There are numerous grades of steel pipe, and I assume numerous grades of genuine wrought iron pipe; and when we speak of brass pipe, as I recall, there are numerous compositions of brass pipe. Do your records—do Mr. Schneider's records give us any details as to the electrolysis, or the electrical conditions—the effect of electrolysis on the different percentages of copper and tin in the brass pipe—as to the best percentages. I do not believe that the pipe manufacturers make fittings. Should we try to get the brass fittings containing the same proportion as put into the pipe—that is, copper and tin?

W. G. SCHNEIDER:[2] I am very glad the question is raised. I will dispose of the fitting question first. Brass is an alloy of copper and zinc, and most fittings are cast of mixtures that contain about 65 per cent copper or more, because they are readily cast, and for certain advantages in manufacture.

These fittings so closely approximate the composition of the pipe that any difference of potential that may be set up is negligible and will not cause electrolysis. I have never heard of a failure of a fitting due to electrolysis set up between the fitting and the pipe. Where copper pipe or high copper content brass pipe is used, it

[7] Superintendent, Water Works, Herkimer, N. Y.

would be good practice to obtain high copper content fittings containing say 80 per cent copper. They are readily obtainable and cost very little more than other fittings. Do not use iron fittings with brass pipe as any electrolysis will corrode the iron.

There are various mixtures of brass pipe on the market today. There is the 60:40 mixture which contains about 60 per cent copper and 40 per cent zinc. There is the 2:1 mixture, which contains about 65 per cent copper and the rest zinc. Then we have the 70:30 mixture, which is 70 per cent copper and 30 per cent zinc; a variation of this would be 70 per cent copper, 29 per cent zinc, and 1 per cent tin, which is Admiralty piping. It is used regularly by the government for the handling of salt water and is also used in the Atlantic City hotels today to handle salt water. It has been used for many years and has given good service.

Another composition is 80 per cent copper and 20 per cent zinc. This covers the range of alloys that are regularly made up as brass plumbing pipe. In the great majority of installations in New York City, Boston, Cleveland and all over the country, the 60:40 mixture has proved satisfactory. There are exceptional localities, such as Newton, Massachusetts; Pittsburgh, Pennsylvania, brought out by the gentleman who referred to water contaminated with wastes from pulp mills, where it is necessary to use a higher copper content piping, but such are special installations. If you are buying your piping from a good manufacturer he will give you the right mixture. In fact, in the brass industry good manufacturers endeavor to furnish the proper mixture to those districts where it is intended to be used. With proper installation and proper piping you should not have trouble where you are conveying water that is fit to drink. Have I answered your question?

A. T. CLARK:[7] Well, yes; but how do these manufacturers know what is proper, if you have never used brass pipe in your territory? That is one of the points. And the other was, Do you get electrolysis between your fitting and your piping? Do you have a different proportion of copper in your fitting than in your piping?

W. G. SCHNEIDER:[2] The life of the piping material which you are using, together with a consideration of the water conditions, is a basis on which the proper mixture of brass pipe may be recommended. There is practically no electrolysis between the fitting

and the pipe for the difference of potential set up between a brass fitting of 65 per cent copper, and brass pipe which is 60 per cent copper is very small and there is no danger of the electrolysis taking place.

E. S. COLE:[8] Mr. Chairman, I should like to ask Mr. Schneider one question that might throw some light on this last question. I thought Mr. Schneider might be willing to tell us whether the hardness or tempering or other things used has an effect on the hardness or tempering of the pipe.

W. G. SCHNEIDER:[2] It certainly has. Fifteen years ago, when the use of the microscope by brass fabricators was not as general as it is today, this question could not be studied as it is today, with the result that pipe in those days was in some instances shipped "hard." As time went on the strains that were still in that pipe due to drawing operations caused cracking or what is known as "season-cracking."

Today for a piece of brass pipe to season-crack means carelessness or "faulty manufacture." Brass pipe nowadays does not season-crack when it comes from a good manufacturer, for samples of the pipe are examined microscopically. By this means it is possible to determine whether that piping is in the proper condition and whether the strains which might cause cracking have been relieved. All good manufacturers of brass pipe give the piping, after it is drawn, an anneal so as to relieve the strains set up by the drawing operations. Today brass piping for plumbing is semi-annealed, meaning it is relieved of its strains and will not season-crack.

A. F. RELKNER: The gentleman across the way asked for the difference between tubing and iron piping. I might say that it is not necessary to go to England to get information on that line. Our company has all that information and will be glad to supply it. We have worked out a connection whereby it is possible to eliminate the threading entirely. That in turn brings the cost down, so that you get more feet per pound. We will be glad to give you any further information. I believe it is known now that copper and brass are considered the metals.

[8] President, The Pitometer Co., New York, N. Y.

J. W. ACKERMAN:[6] I do not know whether this is a proper thing to bring before this meeting, but I thought from your statement a few minutes ago that your concern stands ready to advise a water works plant as to the kind of piping that they think would be best suited to their particular water.

W. G. SCHNEIDER:[2] We stand ready to advise to the best of our ability with the best information which we have or can obtain, any water works, municipality or company, or any sheet metal worker, or any manufacturer using our products; to give the best possible information which we have and which it is possible to obtain. We are glad to advise and glad to coöperate with anybody at any time.

F. W. GREEN:[9] I would like to say a word or two on corrosion. I believe Mr. Nicol said it is pretty well understood about corrosion, and it surprised me, because I understood the American Chemical Society at their meeting in Baltimore next month, April, are going to devote a good deal of time to the subject of corrosion. I want to refer to an experiment made along this line at Philadelphia. They took some water and boiled it and then added iron and reboiled this water. They found that the second time they boiled the water they had some iron in it, and found that the water was just as corrosive after having been boiled the first time as it was afterwards.

We carried it a point further, and took some water and boiled it and other water that was unboiled, and left it at the room temperature, and found that the water was still corrosive, although the oxygen had, of course, been boiled out of it.

We have always been led to suppose that corrosion was due in some way to the carbonic acid and the oxygen and algae. But in this case, and the same is true of the Philadelphia water, it did not seem to hold. So I do not feel that we do know a great deal about corrosion.

W. G. SCHNEIDER:[2] We know something about corrosion, but not very much. Everybody is writing about it. I guess everybody is reading about it. Many articles and books have been published on the theory of corrosion, and every once in a while new theories and thoughts are advanced so that I hope I have not conveyed the impression that we know all about corrosion.

[9] Superintendent, Filtration and Pumping, Passaic Consolidated Water Co., Little Falls, N. J.

W. W. BRUSH:[10] I wish I could tell you what we should use for services and for the piping within the houses. But this is a very difficult problem which has not yet been solved.

Mr. Schneider has given us a special plea for brass and copper piping. Dr. Hale, as I recall, has told me of a case in New York where Catskill water is used, where a house was piped, and where the owner is dissatisfied due to the discoloration of the plumbing fixtures which have been occasioned by the copper blue color coming from the water which passed through the brass pipes.

In my apartment I noted, after months, that an extremely slow drip, so slow that I could not note the water dripping from the tub faucet, caused a blue discoloration. Such discoloration is very difficult to remove with the ordinary cleansers that are used in the household, and it is disagreeable and objectionable to the householder.

With the algae difficulties and the tastes that we have, I do not know what would be the effect of brass or copper pipe on the taste of the water. I have personally noted that, when I have drawn water in a silver pitcher, the taste from algae is intensified by a relatively short period of standing in the pitcher; i.e., the time between the draft from the faucet and the time of service at the table, which may in the course of a meal be twenty minutes to half an hour. This increase in taste has been noticed not only once but on numerous occasions, and by others than myself, and is due to actual destruction of the algae by silver salts. Presumably the same thing would occur, and perhaps to a greater extent, with copper salts in brass piping.

In New York, we advocate lead for services, and generally lead has been used. But we are, rather concerned over the possbility of the lead poisoning which may result from the use of the lead with a soft water, and if we could be certain that copper or brass represented the material to be used for services there would be certainly no hesitation in immediately making a change and requiring the copper or brass.

The cement-lined pipe has been used successfully in many places for many years, and it seems to me that it is essential that each water should be considered separately, as each water has some differences in chemical constituents and in reactions. It would be most helpful if the chemists and those who have given their time especially to this problem would try to work out those standards that would enable us

[10] Deputy Chief Engineer, Department Water Supply, Gas and Electricity, New York, N. Y.

to judge in a general way what material with a given water supply would probably be best suited for services and for piping within a building.

I assume it is rather difficult to advise a man not to use copper or brass if you are trying to sell that product. In the same way, it is difficult not to advise the use of steel, if you are trying to sell that product. It is such an important matter from the viewpoint of giving satisfaction to the consumer that it does seem that the manufacturer might rise above the commercial side, and try to advise in an unbiased manner as to what material is best suited for a particular water.

It is difficult to prove to the speculative builder who is putting up a house today and who is to sell that house as soon as possible, and most of the builders in New York are speculative builders, that he should put in anything but the cheapest piping he can buy. The owner does not know what he is buying, and if the builder advertised that he had copper piping instead of iron piping, and charged a few dollars more for his house, the majority of the purchasers would go past his house and look at the others.

It is, therefore, not a particularly valuable selling point to say that your house has copper or brass piping. Yet we all know that, due to the corrosive waters in this section of the country, in probably a dozen years there will be trouble from the iron piping.

I believe that the American Water Works Association will be more and more helpful each year in aiding in the solution of this problem of what we should use for services and what we should advocate for builders to use within a house. Any water works man who attempts to say that this, that, or the other material represents the answer for service pipes, or represents the answer for the hot- or cold-water piping within a building, is undertaking to say something that he can not successfully maintain by his own experience. He is not helping to the extent which we hope to receive help from the Water Works Fraternity—that is, looking for what is needed for the particular water that each member has to deal with.

W. G. SCHNEIDER:[2] Regarding the point just raised; first I should like to say a word about the blue discoloration, which is the same question that was brought up by Mr. Weston at the Water Works Association's Convention at the Hotel Astor, New York. He brought out very forcibly the fact that the blue discoloration had

developed. Another gentleman from the same territory, Mr. Heffernan, together with several experts on the subject, investigated this particular problem and found a very heavy ground from a nearby trolley line. As soon as this ground had been cleared up there was no further difficulty and the blue discoloration ceased. A blue discoloration does not result where a proper installation of brass pipe or copper pipe is used for potable domestic water. If a blue discoloration is noticed extraordinary conditions prevail that should be immediately looked into.

As to the other remarks of Mr. Brush, I wish to say that I am a member of the American Water Works Association, and while I represent the manufacturers of brass and copper piping, I am not actually selling the product myself. Any information which I may have given has been given to the best of my technical knowledge and belief. If any other material were better piping material than copper or brass it would be absurd on my part to endeavor to convince you of what is not so.

The Copper and Brass Research Association which I represent has collected a great many water analyses from all over the country, Canada and other places. I find, however, that for any private individual or corporation to undertake to collect and interpret water analyses is a very difficult task for the requisite complete water analyses and other desirable information are not easily obtainable or available.

I believe the Water Works Fraternity itself, either individually or through the American Water Works Association, could materially help in the gathering of the data what would go toward solving its problems. For instance, where a chemical analysis of the water is made, why not make it a point to determine those factors that have a bearing on corrosion as well as those others now regularly determined? Do not misunderstand me, I do not wish to convey the impression that with a water analyses alone we can say what the material should be to resist corrosion. In some instances with complete analyses and with other obtainable information, it is possible to do this. However, it is not always possible to determine from the chemical analysis the combinations or the form in which the constituent is contained in the water. Catalytic action, pressure, heat, velocity, all have their bearing. I believe that the theoretical data, when considered in conjunction with the actual corrosion of piping materials, afford a good index as to what might be reasonably expected.

All the commercial metals which we have available for water piping arrange themselves into what is known as an electrochemical series. Starting with the most electro-positive and ending with the electro-negative we have steel, iron, lead, brass, copper. Unfortunately for steel it is the most electropositive and most easily corroded, whereas brass and copper are the most electro-negative or least easily corroded. Whenever any of these metals are acted on by moisture, or where corrosion takes place, dependent on a difference of potential that may be set up, the more electro-positive the metal or the higher the difference in potential the greater the corrosion. Consequently under the same service conditions, where a difference of potential is developed, it will be greatest with iron or steel and least with brass or copper. Excluding straight chemical corrosion, which is the exception rather than the rule, it is an absolute fact that under the same service conditions brass or copper will outlast steel or iron as plumbing pipe many times over.

SOL PINCUS:[11] I understand, in some of the apartments in New York City, that they periodically use some compound to give a coating, or protective coating, as being suited to the piping system in the building. I think those compounds very frequently contain silicate of soda. I wonder what the New York Water Department says as to the use of such compounds, whether they sanction it, or not.

W. W. BRUSH:[10] I think about three years ago it was brought to our attention that one of these compounds was being pushed in New York City. We did not know what the effect of the compound would be on the health of the individual who might get a shot of the compound when he was not supposed to get it. So we took it up with the Health Department, and they in turn asked us to coöperate with them, and we went to several places where the compound had been introduced.

We found that the company that was pushing it did not make sufficient provision to safeguard the individual from possibly getting a heavy dose of the compound. The instructions were such that even, if followed, they might result in the compound being drawn by the consumer.

The manufacturer tried to arrange a method whereby it would be introduced in the piping when there was nobody in the building.

[11] Sanitary Engineer, New York, N. Y.

I do not know whether the Health Department did or did not prohibit the use of the compound.

There certainly should be nothing introduced into the water system unless it has the approval of the local Health Department.

I trust that Mr. Schneider did not obtain from my remarks the idea that I was accusing him of making a plea that was an improper plea for brass or copper piping. I think we will all admit—even those who represent iron piping—that the brass and copper piping will generally last very much longer than iron piping and that the iron piping without a protective coating is an unsatisfactory piping for the eastern part of the United States.

In the other sections of the United States, where they do not have the corrosive waters that we have in this section, I understand that this particular problem is a very much less difficult one to handle. I think Mr. Schneider is helping in every way in giving us information that will be an aid in determining what sort of materials we should use.

We should all recognize that there is a great deal more work to be done. All of us should aid in as far as possible. Many of the large communities should spend more money and time than they have been spending, in experimental work that can be carried on so as to give us a more satisfactory piping for conveying the water from the water main into the house and through the house.

F. E. HALE:[12] Mr. Chairman, I wish we knew that brass or copper pipe were a panacea for corrosion under all conditions in water supply. Each water supply and the particular conditions must be considered in each case. Referring to the statement of Mr. Brush regarding the blue stain caused by water passing through brass pipe, the instance was that of a complaint in Brooklyn in March, 1924. An old house had had the iron piping replaced with brass piping upon recommendation and the occupants complained of a blue stain upon the white porcelain sinks and asked us to investigate it as they were afraid of poisoning. Analysis of the water on the top floor where the draft was least frequent indicated the presence of copper to the extent of 0.4 p.p.m. This was considered to be due to the fact that the installation was new and the parties were advised that the amount was too small to injure the health and that it would probably

[12] Director of Laboratories, Dept. of Water Supply, Gas and Electricity, New York, N. Y.

gradually grow less due to formation of a coating upon the inside of the pipe. This opinion was corroborated by analysis of the water made in December, which showed 0.10 p.p.m. copper. Copper and brass are subject to some corrosive action and, while technically rusting may not take place because the term "rust" applies to iron only, from a practical standpoint rusting does take place in the formation of this blue color, at least when the pipe is new. I have been informed by plumbers that a bluish coating forms on the inside of brass piping.

To mention an unusual instance, several years ago we investigated a complaint from a house in Brooklyn, where there was an installation of brass pipe and a copper boiler. A piece of the brass pipe had to be replaced, since it was completely clogged by a deposit. Analysis of this deposit showed it to consist largely of copper and zinc phosphates. Inspection disclosed two filters in the basement, one containing sand and the other charcoal. The charcoal proved to be bone-char. The water evidently dissolved phosphate from the bone-char and deposited phosphates of copper and zinc which had dissolved from the piping. This was the action in the hot water system.

To mention another instance, I am informed by engineers that the copper tubing in preliminary heaters to steam boilers are corroded by boiler feed water which contains soda ash.

Copper is acted on under many conditions. Several years ago I purchased some Monel metal screening and installed it at my house, which is 2 miles off the ocean. The screen doors have been in service winter and summer. In the spring and the fall when the dampness is sufficient to condense upon the screens, the corrosion is so great that a blue stream stains the porch and the mesh of the screens become entirely closed with a film of dissolved metal and yet personal laboratory tests have shown Monel metal composed of copper and nickel to be very resistant to corrosion.

One must keep in mind certain established facts concerning corrosion of metals. There are two steps in the process; first, the putting into solution of the metal; second, the available oxygen for continuing action.

The first action governs, to a large extent, the rapidity of corrosion. The second governs the total amount of corrosion which can take place.

The conditions which govern the first reaction, i.e., solubility, differ in the case of different metals. In the case of iron it is due to

acid conditions, such as carbonic acid, soil acids, etc. In the case of brass compounds containing zinc, corrosion is greater in alkaline solution. Alkalies do not attack iron, but readily dissolve zinc, aluminum, tin and certain other metals. Softened waters containing excess alkali might readily act entirely differently upon iron and brass, although a small excess alkali will speed up corrosion of iron.

In the ordinary distribution system of water supply the presence of oxygen does not play the chief part because nowhere near the amount of total corrosion takes place which can take place due to the oxygen in the water supply. One part per million of oxygen will produce 10½ p.p.m. of iron through corrosion in total reaction, but an encrustation forms on the inside of pipe and retards corrosion to such an extent that the oxygen content of the water is hardly reduced from the time it enters the distribution system to the time it flows from the taps in the houses. On clean iron piping reaction is so rapid that all the oxygen will be used up in 18 hours or practically over night in such a water as the New York City Croton supply. This explains complaints from new installations.

I wish to correct the statement of Mr. Brush regarding the use of silicate solution to stop corrosion. As far as I am aware, the Board of Health has taken no action to stop its use. It is still in use, at least in hot water systems, and I have been informed in many instances that its action has resulted very favorably in diminishing red water trouble.

A. M. JOHNSTONE:[3] Some time ago Mr. Schneider spoke about the analyses of water, and that the Association had considerable difficulty in securing such analyses because the water works men would not send them in. Now that, of course, is very reprehensible and I am sure the duly elected Board of Governors will probably make it its business to look into it, but I must enter a little defense for the Water Works Association, because during the course of my work I have occasion so many times to ask for analyses of water and I must say invariably I can get them. When they have not given them in the form in which they are most valuable I have no difficulty to get them according to my desire.

On that subject I might ask Mr. Schneider if an analysis were available to him in detail and in the form that he desired would that indicate the type of piping that would be best fitted for any given service?

W. G. SCHNEIDER:[2] I am sorry if I have stated or conveyed the impression that the water works men are not coöperating fully. Such is not the case; they have always furnished all the information available and have been more than anxious to coöperate to the fullest extent possible. What I endeavored to convey was a plea for the determination of more information than they have available at the present time.

The analysis will not, by itself, determine the piping material; in the majority of instances it will help to a certain extent and it gives valuable data to have available in connection with any water problem.

About the blue discoloration mentioned by Dr. Hale, they are exceptional instances due to extraordinary conditions. From my experience I am lead to believe that there is "something wrong somewhere" and that the piping material is not to blame. I am perfectly willing to visit personally the house where this discoloration occurs and endeavor to locate the trouble, if this is possible without conducting extensive tests.

Dr. Hale referred to the action of alkalies on brass and stated that zinc compounds were formed. Where waters are specially treated with chemicals the subject should and must be given special consideration. With domestic drinking water no such action has ever been heard of or observed. If it did occur there would be no object in using galvanized iron or steel pipes as the galvanizing which is zinc would in no way help to protect the piping. With the proper brass pipe in use where unusual conditions prevail there is no free zinc. The zinc is all combined with the copper to form a new metal—brass—on which an alkaline domestic drinking water will have no effect.

I do not agree with everything Dr. Hale has said relating to the theory of corrosion, especially as to the effect of oxygen, but this is another matter and time forbids discussing this technical subject at this time.

F. H. LUCE:[13] On the subject of introducing a compound for the corrosive waters in the City of New York, I want to say that in the section where I live, Forest Hills, it is being done quite extensively and circularized every once in a while by a local agent of that sec-

[13] Superintendent, Woodhaven Water Supply Co., Woodhaven, N. Y.

tion; and so far as the removal of corrosion is concerned, I think it is very effective.

I do not know about any other results. Regarding the life of piping, my experience—and that seems to me to be best thing on which to base a conclusion—has shown that it comes back to the question of the water. In the place where I lived a great many years, Woodhaven, and where I still have my business, we have a local water supply. I built a house there in 1890, and put in ordinary steel galvanized pipe, and it is there yet, giving a good supply of water. I have not heard of anything in the way of corrosion occurring there.

I built a house a couple of years ago in another section, not far away, in Forest Hills, and I never took the water into consideration because of the fact that I had never heard of corrosion in our place. I used galvanized iron pipe. In two years I have just had to rip those out because of the fact that the water was unusable. I spent hours trying to draw a bath tub full of water that could be used. My conclusion is that it depends upon where you happen to be, and the water supply that you have there. If I were building a house in Woodhaven I would use galvanized steel pipe; but if I were again building a house in Forest Hills, I would use all brass or copper pipe.

B. B. HODGMAN:[14] Before this meeting adjourns—I have no desire to break up the discussion—there is a question concerning these meetings that I would like to bring up. We sent out 570 odd notices and got 75 acceptances and 70 present. I would like to find out if there is a reason for it. Perhaps they are not interested in the subjects we are bringing up and if they are not I wish somebody would suggest subjects, because it is hard enough for us to pick them out ourselves.

I would like to have suggestions for next year. We are planning now to have two meetings next year—one in Albany in the fall and one in Buffalo in the spring, when they expect probably to open their filtration plant, and two meetings in New York. But it does seem that when we are going to get an attendance of 70 out of a membership of over 570, there is something wrong.

D. W. FRENCH:[15] I think that Mr. Hodgman ought to bear in mind that next year we are going to have a new secretary.

[14] Civil Engineer, New York,N. Y.

[15] Superintendent, Hackensack Water Company, Weehawken, N. J.

To get back again to this subject of brass pipe, I think we have had a very interesting meeting and Mr. Schneider's contribution to it, together with his invitation to take up with him any questions that might arise in connection with its use, is one that may prove very helpful to many of us in the future.

I do not claim to know any more about brass pipe installation and probably not half as much as most of you men, but more than twenty years ago we put in a lot of brass pipe work for feed and blow-off lines for our 500 horse power boilers at our main pumping station. This pipe never gave us any trouble, never had a leak in it, never had anything happen to it and has never required any attention.

About twenty-two years ago I was responsible for the installation of brass pipe in a large residence on Long Island. The house had a great many fixtures and twelve bath rooms. A year or so ago I had occasion to look over this work and was pleased to learn that the installation had given perfect satisfaction, no leaks had developed, no breaking of any part of the pipe system, and no renewals of any kind. We have had a large experience in service installation work, using various kinds of pipe, and I feel sure that one of our mistakes in the early installations was in using pipe too small in diameter. Much of our work of twenty or thirty years ago was $\frac{1}{2}$ and $\frac{5}{8}$-inch services with a $\frac{1}{2}$-inch corporation cock, and we have been obliged to renew many of these old services because of an insufficient supply.

The smallest installation now consists of a $\frac{3}{4}$-inch corporation cock, $\frac{3}{4}$-inch lead gooseneck, $\frac{3}{4}$-inch brass pipe and a $\frac{3}{4}$-inch inverted curb cock which is satisfactory for both $\frac{1}{2}$- and $\frac{3}{4}$-inch meters. We follow the same practice in 1-inch services, and in sizes larger than 1-inch cast iron pipe is used exclusively.

When we first used brass pipe we ordered the regular brass pipe I. P. S. and had some trouble with it. The material was too hard and brittle and lacking in flexibility. Several of them broke transversely and were necessarily renewed. When making preparation to order our supply for 1925, I first called upon our friend Mr. Schneider and we went into the matter thoroughly. He supplied me with a copy of the specification prepared by the American Society for Testing Materials, together with the names of the best manufacturers of brass pipe. We received bids for 135,000 feet in February this year, part of which contract has been delivered and we are now making installations at the rate of about 500 per month. We are very much pleased with the new material in every way and it is giving complete satisfaction.

I think we all admit that the weak point in any pipe, be it brass or iron, is at the thread. In threading we must of necessity cut away about 50 per cent of our metal, and any part of the thread which is left exposed outside of the couplings or other fittings is inviting attack at that point, and will be the point which will first give trouble.

At the present time I am trying to protect this weak point by a slight change in patterns which provides for a counterbored fitting, with the thread beginning $\frac{1}{4}$-inch back from the face, the effect of which will prevent any part of the thread being exposed or coming in contact with the ground. The cement used in making the joints will fill up and harden in the counterbore. This little detail will not add any strength to the job, but I do believe it will add something to the length of the life of the pipe by protecting to some extent its weakest point, and at a very insignificant expense.

PROPOSED RAPID METHODS OF WATER ANALYSIS FOR BOILER PURPOSES (APPLICABLE TO RAILROADS AND SMALL STEAM PLANTS) WITH INTERPRETATION OF RESULTS[1]

INTENTION

This subject is assumed to cover only the rapid methods of analyzing directly applicable to boiler waters. The methods given are not intended to supplant the more time-consuming and more accurate methods used where more detailed information is required than is necessary in field surveys, routine control of water softening plants, and the approximate determination of the minerals usually effecting steam boiler operation.

The purpose of the standard rapid methods of boiler water analysis and interpretation of results is to promote uniformity and understanding of the effects caused by various constituents normally found in boiler water supplies, and to enable intelligent judgment to be passed quickly on the quality of the supply without full and detailed explanation as to each of the methods of analysis employed. The following appears to include the best of current practice, which will, of course, be subject to change as improvements in analytical procedure are developed and chemical changes in the steam boiler are better understood.

GENERAL

The general practice for reporting water analysis for steam purposes is in terms of grains per United States gallon, which is equivalent to parts per 58341. This appears to convey a better impression to the users, of the actual condition of the water, which is the ultimate purpose of the analysis, and it is recommended that reports of water analysis in grains per gallon with supplementary advice as to pounds per 1000 gallons of total incrustants, total non-incrustants, and total solids, be adopted as standard practice.

[1] Prepared by R. C. Bardwell, referee, and submitted as a part of the work of Committee No. 1, Standard Methods of Water Analysis.

The members of the Association are requested to try the procedures herein set forth and to forward their comments thereon to the Chairman of Committee No. 1, J. J. Hinman, Jr., Iowa City, Ia.

It will be noted that in the following recommended methods, the customary standard solutions are used and that a 58.3 cc. sample or aliquot portion thereof, is taken for analysis so that the result will be given direct in grains per gallon. If the reports are desired in terms of parts per million, a 100 cc. sample or aliquot portion thereof, can be used with the same solutions and the results as found direct, can be multiplied by ten to read in parts per million.

FORM AND COMBINATION

Although the actual determination of substances in water are usually made in terms of the various elements or radicals, the customary and accepted method for reporting results of water analysis for boiler purposes is by hypothetical combinations of the elements. The following scheme is recommended for purposes of uniformity:

Silica, as found, except in alkaline waters containing alkali silicates.

Iron and aluminium oxides—as found, except in special cases of acidity where more extensive determination should be made.

(Iron is usually present in well waters as ferrous bicarbonate, though in highly colored surface waters it may be partially in organic combination. In the former case the free and half bound carbonic acid act corrosively, being set free upon exposure to the air, or by heat in a boiler with accompanying precipitation of ferric oxide.)

Make combination of the positive radicals determined with the negative radicals as found, in the following order:

Positive radicals	*Negative radicals*
Calcium	Carbonate
Magnesium	Sulphate
Potassium	Chloride
Sodium	Nitrate

INTERPRETATION OF RESULTS

Incrustants. It is understood that silica, iron and aluminium oxides, and the calcium and magnesium combinations will be classed as incrusting solids.

Non-incrustants. The sodium compounds and other alkali metal combinations, as well as organic substances will be classed as non-incrusting.

Corrosive. All acids, iron and aluminium sulphates, calcium chloride and nitrate, magnesium sulphate (in appreciable amount), chloride and nitrate will be classes as corrosive salts. Free or half bound

CO_2 in appreciable amounts, and O_2 where pH is below 10, will also fall in this class.

FIELD SURVEY OR RAPID CHECK TESTS

General

Field survey tests for boiler waters are generally confined to a means of approximating the total hardness or total amount of scale forming matter which the water contains, and the division of this figure into alkalinity (carbonate hardness) and the non-carbonate hardness, as well as an approximation of the ratio of calcium and magnesium salts. With experience in manipulation, the following procedure can be made to give close and satisfactory results.

REAGENTS

1. Standard calcium chloride solution. Dissolve 0.5 gram of pure calcite (calcium carbonate) in a little dilute hydrochloric acid, being careful to avoid spattering. Wash down with distilled water and neutralize with ammonium hydroxide to slight alkalinity using litmus as an indicator. Make up to 500 cc. with carbon-dioxide-free distilled water and store in a glass stoppered bottle. One cubic centimeter of this solution is equivalent to 1 mgm. calcium carbonate.

2. Standard soap solution. Make up stock solution by shaking vigorously, approximately 100 grams of powdered castile soap or sodium oleate in one liter of 80 per cent grain alcohol. Let the solution stand at least over night. Dilute the clear supernatant liquid with 70 per cent grain alcohol, until 1 cc. of the resulting solution is equivalent to 1 cc. of the standard calcium chloride solution, making due and recorded allowance for a lather factor which will vary from 0.7 to 1.4 cc. with different soaps. One cubic centimeter of this solution after subtracting the lather factor is equivalent to 1 mgm. calcium carbonate.

(Note: This solution is approximately five times as strong as the solution recommended in the "Standard Methods of Water Analysis," A. P. H. A., 1923. The solutions and method described therein may be substituted for the method herein described, if desired.)

3. N/50 sulphuric acid.

4. N/50 sodium carbonate.

5. Phenolphthalein.

6. Methyl orange indicator.

It will be noted that in the following recommended methods, the customary standard solutions are used and that a 58.3 cc. sample or aliquot portion thereof, is taken for analysis so that the result will be given direct in grains per gallon. If the reports are desired in terms of parts per million, a 100 cc. sample or aliquot portion thereof, can be used with the same solutions and the results as found direct, can be multiplied by ten to read in parts per million.

FORM AND COMBINATION

Although the actual determination of substances in water are usually made in terms of the various elements or radicals, the customary and accepted method for reporting results of water analysis for boiler purposes is by hypothetical combinations of the elements. The following scheme is recommended for purposes of uniformity:

Silica, as found, except in alkaline waters containing alkali silicates.

Iron and aluminium oxides—as found, except in special cases of acidity where more extensive determination should be made.

(Iron is usually present in well waters as ferrous bicarbonate, though in highly colored surface waters it may be partially in organic combination. In the former case the free and half bound carbonic acid act corrosively, being set free upon exposure to the air, or by heat in a boiler with accompanying precipitation of ferric oxide.)

Make combination of the positive radicals determined with the negative radicals as found, in the following order:

Positive radicals	*Negative radicals*
Calcium	Carbonate
Magnesium	Sulphate
Potassium	Chloride
Sodium	Nitrate

INTERPRETATION OF RESULTS

Incrustants. It is understood that silica, iron and aluminium oxides, and the calcium and magnesium combinations will be classed as incrusting solids.

Non-incrustants. The sodium compounds and other alkali metal combinations, as well as organic substances will be classed as non-incrusting.

Corrosive. All acids, iron and aluminium sulphates, calcium chloride and nitrate, magnesium sulphate (in appreciable amount), chloride and nitrate will be classes as corrosive salts. Free or half bound

CO_2 in appreciable amounts, and O_2 where pH is below 10, will also fall in this class.

FIELD SURVEY OR RAPID CHECK TESTS

General

Field survey tests for boiler waters are generally confined to a means of approximating the total hardness or total amount of scale forming matter which the water contains, and the division of this figure into alkalinity (carbonate hardness) and the non-carbonate hardness, as well as an approximation of the ratio of calcium and magnesium salts. With experience in manipulation, the following procedure can be made to give close and satisfactory results.

REAGENTS

1. Standard calcium chloride solution. Dissolve 0.5 gram of pure calcite (calcium carbonate) in a little dilute hydrochloric acid, being careful to avoid spattering. Wash down with distilled water and neutralize with ammonium hydroxide to slight alkalinity using litmus as an indicator. Make up to 500 cc. with carbon-dioxide-free distilled water and store in a glass stoppered bottle. One cubic centimeter of this solution is equivalent to 1 mgm. calcium carbonate.

2. Standard soap solution. Make up stock solution by shaking vigorously, approximately 100 grams of powdered castile soap or sodium oleate in one liter of 80 per cent grain alcohol. Let the solution stand at least over night. Dilute the clear supernatant liquid with 70 per cent grain alcohol, until 1 cc. of the resulting solution is equivalent to 1 cc. of the standard calcium chloride solution, making due and recorded allowance for a lather factor which will vary from 0.7 to 1.4 cc. with different soaps. One cubic centimeter of this solution after subtracting the lather factor is equivalent to 1 mgm. calcium carbonate.

(Note: This solution is approximately five times as strong as the solution recommended in the "Standard Methods of Water Analysis," A. P. H. A., 1923. The solutions and method described therein may be substituted for the method herein described, if desired.)

3. N/50 sulphuric acid.

4. N/50 sodium carbonate.

5. Phenolphthalein.

6. Methyl orange indicator.

Analytical procedure

1. Hardness. Measure 58.3 cc. of the water into an 8-ounce bottle. Add the standard soap solution 1 cc. at a time, shaking vigorously after each addition, until a strong permanent lather is secured. As the end point is approached, cut the additions of soap solutions to 0.5 cc. Make note of any false end point, which is the dividing line between the calcium and magnesium salts. If a false end point is noted, record. The final end point after deducting the lather factor, gives the total hardness ("H") as grains per gallon in terms of calcium carbonate. (In determining the hardness of acid waters they should first be rendered neutral to methyl orange by addition of N/50 sodium carbonate solution. Samples containing appreciable amounts of free carbon dioxide should be neutralized to faint pink with N/50 normal sodium carbonate solution before testing.) The difference between the false end point and the total hardness indicates the amount of magnesium salts, the balance being calcium salts, all expressed as grains per gallon in terms of calcium carbonate. If the hardness test requires more than 15 cc. of soap solution, it is best to take an aliquot portion and dilute to 58.3 cc. with recently boiled distilled water so that the lather point will require less than 15 cc. Multiply result accordingly to obtain correct hardness value.

2. Alkalinity. Titrate 58.3 cc. of the water under investigation with N/50 sulphuric acid solution, using methyl orange indicator and record as "alkalinity." The number of cubic centimeters of N/50 sulphuric acid solution used gives the carbonate hardness direct as grains per gallon in terms of calcium carbonate.

In the case of alkaline waters, if the total hardness is greater than the alkalinity, the difference between the two represents the non-carbonate hardness. If the total hardness is less than the alkalinity, the difference is sodium carbonate, all of the hardness being then in the form of carbonate hardness. The hardness due to calcium and magnesium salts is indicated by the false and true end points in the hardness test. In the case of acid waters, all of the hardness will be non-carbonate hardness.

3. Negative alkalinity of acid waters. In case the water under investigation is acid to methyl orange indicator, titrate 58.3 cc. of the water with N/50 sodium carbonate solution, using methyl orange indicator. The negative alkalinity (or acidity) is obtained direct as grains per gallon in terms of calcium carbonate.

4. Alkalinity of treated waters. When the water under investigation is treated water, titrate 58.3 cc. of the water with N/50 sulphuric acid solution, using phenolphthalein indicator. Double the reading and record as, "causticity modulus" ("C").

Add methyl orange indicator to the colorless solution and continue the titration with N/50 sulphuric acid solution, recording the final reading direct as "Alkalinity" ("A").

The determination of the hardness ("H") of the water is made as outlined above.

The difference between the hardness ("H") and alkalinity ("A") shows an overtreatment in soda ash if the alkalinity ("A") is in excess, or an undertreatment if the hardness ("H") is in excess, all directly as grains per gallon in terms of calcium carbonate. Likewise, the excess of the causticity modulus ("C") over the alkalinity ("A") indicates an overtreatment with lime or caustic soda, while an excess of alkalinity ("A") over causticity modulus ("C") shows an undertreatment, either being direct as grains per gallon in terms of calcium carbonate. In other words, this difference shows the excess of deficiency of hydrate alkalinity.

RAPID LABORATORY METHODS

General

The methods are recommended for routine laboratory procedure where it is desired to obtain quick results of accuracy sufficient to differentiate between constituents normally present in waters, and to furnish sufficient information for making an ordinary analytical report which will permit a judgment to be made as to the general effect of the quality of the water examined on boiler use.

Reagents

1. Standard soap solution. Prepared as described above.

2. N/50 sulphuric acid solution.

3. N/50 sodium carbonate solution.

4. N/20 soda reagent. Prepared by mixing equal volumes of N/20 sodium hydroxide solution and N/20 sodium carbonate solution.

5. Standard sodium chloride solution. Dissolve 1 gram of pure sodium chloride in 1 liter of distilled water. One cubic centimeter is equivalent to 1 mgm. NaCl. (Note: The basis of this solution is

different from that used in sanitary water analysis and which is based on a definite amount of Cl, not NaCl.)

6. Standard silver nitrate solution. Weigh out about 2.906 grams of silver nitrate crystals and dissolve in 1 liter of distilled water. Adjust so that the solution is equivalent to solution 5, standard sodium chloride solution. One cubic centimeter is equivalent to 1 mgm. NaCl.

7. Phenolphthalein indicator.

8. Methyl orange indicator.

9. Potassium chromate indicator.

Procedure

1. Total dissolved solids. Evaporate 58.3 cc. of the water (filtered if necessary) under investigation, to dryness in a weighed dish and heat the residue for thirty minutes at 130°C. Cool in desiccator and weigh. The number of milligrams will give total solids as grains per gallon direct.

2. Alkalinity. Titrate 58.3 cc. of the water under examination with N/50 sulphuric acid, methyl orange indicator which gives grains per gallon direct of bi-carbonate, carbonate, and hydrate alkalinity, in terms of calcium carbonate.

(Note: If lime-and-soda-ash treated water is under examination, the causticity modulus and alkalinity should be determined as outlined under No. 4 in "Rapid Check Tests" and calculations entered accordingly. If acid water is under examination, test should be made as outlined under No. 3 in "Rapid Check Tests" and report made accordingly.)

3. Total hardness. The approximation of total hardness for comparative purposes should be made with soap test as outlined under No. 1 in "Rapid Check Tests."

4. Non-carbonate hardness. Boil 116.7 cc. of the water under examination in a 250 cc. Erlenmeyer flask for fifteen minutes. From the result of hardness test already made, calculate the amount of soda reagent which will be necessary and add at least 10 cc. of the reagent in excess (usually 25 cc. is sufficient) making the addition of the reagent by means of a pipette. Boil ten minutes additional. Transfer to 200 cc. graduated flask, cool and make up to the mark with recently boiled and cooled distilled water. Filter off 100 cc. of the liquid, and titrate the clear filtrate with N/50 sulphuric acid solution, using methyl orange indicator. A blank determination

should be made with 200 cc. of distilled water, the same amount of soda reagent and the same treatment. The difference in the amount of N/50 sulphuric acid solution required for neutralizing 100 cc. of the blank and 100 cc. of the sample gives the non-carbonate hardness direct as grains per gallon in terms of calcium carbonate. If the difference is negative, it shows the amount of free sodium carbonate in terms of calcium carbonate.

5. Magnesium. Take 116.7 cc. of the water under examination in a 250 cc. Erlenmeyer flask and exactly neutralize to methyl orange indicator using N/50 sulphuric acid solution. Boil fifteen minutes to expell all free carbon dioxide and then add a solution of saturated lime water, so that as shown by the hardness test there will be at least 10 cc. in excess (usually 25 cc. is sufficient and convenient). Continue boiling water for ten minutes. Transfer to 200 cc. volumetric flask, cool and make up to volume with recently boiled and cooled distilled water. Filter and titrate 100 cc. of the clear liquid with N/50 sulphuric acid solution, using methyl orange indicator. Run a blank determination using the same amount of distilled water, the same amount of reagents and the same treatment. The difference between the amount of N/50 sulphuric acid solution required for neutralizing 100 cc. of the blank and the same amount of the sample, gives the magnesium present as grains per gallon in terms of calcium carbonate.

(Note: If iron is present in appreciable amount it should be removed before applying this method.)

6. Sodium chloride. Titrate 58.3 cc. of water under examination with standard silver nitrate solution using potassium chromate indicator. Result gives sodium chloride direct as grains per gallon.

7. Silica-iron-aluminum. If it appears that the silica and iron-aluminium content is in excess of 1 grain per gallon, it may be well to separate and weigh by the usual gravimetric methods, using 291 cc. sample and multiplying decigrams by two (2) to obtain grains per gallon. For rapid determination of iron the colorimetric method for total iron, prescribed in the A. P. H. A. standards may be used and the aluminium determined by difference.

8. Sulphate. There is ordinarily but little necessity for making this determination in the usual boiler water analysis as the difference between total solid content and balance of calculated constituents can be taken for the non-incrusting sulphates. If organic matter and nitrates appear high, the gravimetric determination as barium

sulphate may be made, or the turbidimetric method of Muer (Jour. Ind. Chem., 3, 65 (1911)) or rapidly by the Parr sulphotometer.

ALTERNATE OR ADDITIONAL METHODS

9. Calcium. To 116.7 cc. of water add 10 cc. of saturated solution of ammonium chloride and 1 cc. of ammonium hydroxide (1:1). Precipitate the calcium by adding a saturated solution of recrystallized oxalic acid until a faintly acid reaction is obtained as determined by litmus or by the absence of odor of ammonia. Any iron or aluminium precipitated by the ammonia will redissolve. It is preferable to add one-half of the oxalic acid first and rotate vigorously before bringing to acid reaction. Add 5 cc. of a saturated solution of ammonium oxalate, boil vigorously for fifteen minutes, or heat for one or two hours on a steam bath with the beaker surrounded by live steam and filter on asbestos in a platinum gooch crucible previously ignited but not weighed. Wash the beaker four or five times with hot water from top to bottom decanting into the crucible each time. Wash the crucible down once or twice, remove and wash down the outside. The total wash water is usually between 35 and 50 cc. Do not clean the beaker with a policeman but place the crucible in the beaker. Add boiling water sufficient to cover the crucible. Add 10 cc. of sulphuric acid (1:1) and titrate the oxalic acid of the precipitate with N/25 permanganate. Subtract 0.1 cc. for a blank. Each cc. will equal one grain per gallon as calcium carbonate (Hale, Jour. Amer. Chem. Soc., 29, 1078–1085 (1907)).

10. Nitrates. Use A. P. H. A. phenolsulphonic acid method (1912).

11. Carbon dioxide. Use A. P. H. A. method of titration with standard sodium carbonate solution, phenolphthalein indicator. Using 58.3 cc. sample, N/22 sodium carbonate will give reading direct as grains per gallon in terms of carbon dioxide, which N/50 solution will give results direct in terms of calcium carbonate.

12. Dissolved oxygen. Use A. P. H. A. method of titration with sodium thiosulphate.

13. Final report. The following method can be used in calculating hypothetical combinations in the average waters.

In making final report, compare results for non-carbonate hardness and magnesium. If the non-carbonate hardness is in excess of the magnesium, calculate the magnesium to magnesium sulphate.

Calculate the remainder of the non-carbonate hardness to calcium sulphate. The alkalinity then is to be reported as all calcium carbonate.

If the non-carbonate hardness is less than the magnesium, calculate the non-carbonate hardness to magnesium sulphate, and the balance of the magnesium to magnesium carbonate. The magnesium carbonate is subtracted from the value for alkalinity. The difference between the alkalinity and the magnesium carbonate is reported as calcium carbonate.

If the non-carbonate hardness is negative, make proper allowance in the alkalinity value for sodium carbonate, calculate the magnesium to magnesium carbonate, making further allowance in the alkalinity value. The balance of the alkalinity value is due to calcium carbonate.

The difference between the total solids and the sum of magnesium sulphate, magnesium carbonate, calcium sulphate, calcium carbonate, sodium chloride, sodium carbonate, iron and aluminium oxides, gives the amount of non-incrusting, sulphates, nitrates and organic matter. There is ordinarily no necessity in separating these constituents in ordinary boiler water analysis unless after heating the residue from total solids, a black discoloration is noted, indicating a high organic content which might induce foaming of the water in the boiler.

(Note: If the above difference is negative result indicates presence of calcium or magnesium chlorides or nitrates in which case it will be necessary to make the Sulphate (No. 8) determinination in order to calculate the proper amount in the hypothetical combination report.)

FULL AND COMPLETE LABORATORY EXAMINATION

In special cases requiring more accurate data than the above methods would give, it is recommended that the procedure outlined in the "Standard Methods of Water Analysis," A. P. H. A., be employed.

RELATION OF WATER SUPPLY AND SEWAGE DISPOSAL[1]

By George D. Norcom[2]

All water-borne diseases, as far as we are aware, have their source in the waste material of man. How many times we have heard this statement and yet what a frightful price mankind has paid, and is still paying, for this same knowledge! We can only speculate as to the sanitary condition of primitive man, but it is highly probable that time without number he paid for his ignorance with his life. The period in the life of mankind which is covered by written history was replete with epidemics of water-borne disease. No doubt man has always sought a water supply of pleasing appearance, but again and again he has changed these same life giving waters into deadly poisons by the careless disposal of his own waste matter. Out of sight, out of mind is man's age-old attitude toward his waste products and this tendency, together with a large amount of false modesty, has been responsible for the trouble. Being too careless or fastidious to interest himself in sewage disposal man has been content to leave the matter to nature. One early method of sewage disposal was to deposit the material in the back yard near the shallow well. This method is still in use, but gives only temporary relief since the capacity of the back yard is limited. The next development was the cesspool, a large compartment underneath the ground. Unfortunately this filled up and overflowed. As the population increased conditions became unbearable and man hit upon the brilliant idea of dumping sewage into the water courses from which, in many instances, he took his water supply. This is briefly the process of evolution which has at last brought health authorities in every center of dense population face to face with a tremendous problem.

Only within the last fifty years, since the advent of modern bacteriology, has man come to realize the true relation of water supply and sewage disposal and its importance to public health. Even as we look at things today the dividing line between water and sewage

[1] Presented before the North Carolina Section meeting, November 13, 1924.

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is not clearly defined. Take the case of two cities located on the same stream within thirty miles of each other. The city above draws its water supply from the river and having purified it to the desired degree furnishes it to the inhabitants as pure water. Most of the water so supplied finds its way back to the river as sewage. This sewage may have been subjected to some form of purification, since state laws usually demand it, but the fact remains that for every million gallons of water pumped to the city nearly the same amount is again returned to the stream as sewage. This sewage mixes with the river water and after flowing thirty miles some of it is drawn into the intake of the waterworks of the city below and the process is repeated. Let us assume that there are more cities along this river. Assume that as years pass the cities grow rapidly. Eventually we arrive at a point where it is difficult to say which is sewage and which is water. Surely each city lower down on the stream must be drinking a portion of the purified sewage from all the towns higher up. These conditions are not unusual in this country today.

To a certain extent nature has provided for the disposal of sewage. As long as man lived a more or less isolated existance there was little trouble. The earth is able to absorb organic material and by means of organisms it is converted into harmless substances. Water and air are capable of oxidizing a certain amount of organic matter. The sun's rays are the best known agents of disinfection. But man has left the open country and flocked to the city in such numbers that the ordinary provisions of nature have been completely overtaxed in many places. Under the burden of so much waste material the earth becomes sour and unproductive, the watercourses are filled with unspeakable filth, so that no life can exist in them and even the air becomes foul and offensive. Under these conditions it has been necessary to turn to science for relief. By the slow method of experimentation, by the utilization of our meager knowledge of biology, bacteriology and chemistry, by the coöperation of engineers and scientists, the problem is being successfully dealt with, even if not completely solved.

Every waterworks operator is interested in sewage disposal. Water drawn from wells is endangered by drainage from cesspools and privies which may travel beneath the surface of the ground for a surprising distance and penetrate the well by seepage or through a defective casing. A surface water impounded in reservoirs, even

if the watershed be carefully guarded, is in constant danger of pollution from careless individuals. It goes without saying that all unprotected streams and lakes are sewage polluted. During the late war the general rule was that all water supplies were dangerous unless proved otherwise by laboratory tests. This is a good rule and is now applied by most health authorities.

Methods for purifying water have been highly developed. This has been due to a realization on the part of the public of the necessity for pure water. It is a useful commodity for which people are willing to pay. It may be said with reasonable certainty that there are methods available for purifying almost any water providing its pollution load is not too heavy. When the load becomes excessive it is generally expedient to seek a new and less polluted source of supply. Just what constitutes the maximum permissible load for a filtration plant of modern design is a mooted question and provides an interesting field for study.

Unfortunately, methods of sewage disposal are not so well developed. The object to be attained in sewage disposal is not the production of a potable effluent, but to remove the organic matter so that the effluent can be readily oxidized to harmless substances by nature's processes, without the production of a nuisance. The degree of purification required depends on the type of stream which is to receive the effluent. For example, the effluent of a septic tank, requiring as it does huge quantities of oxygen, can be readily disposed of by the dilution it receives when discharged into a large body of water like the ocean. On the other hand the septic process is not adapted to places where the effluent must be discharged into a small stream. In this case it is necessary to employ a combination of methods which may include some form of tank treatment, followed by aeration which is not infrequently followed by chlorine sterilization. The great unsolved problem in sewage disposal is the sludge which continually accumulates. This sludge is bulky since it contains a large amount of water and is unstable, frequently becoming offensive. Many suggestions have been made for its utilization without creating any demand for it. With all his ingenuity man is still confronted with this residue of his waste products and as yet he has not found out how to get rid of it.

While it is usually possible to convince a city of the necessity of spending money to secure pure water, it is not so easy to induce them to spend it for the erection of a sewage treatment plant. Sew-

age cannot be made a popular subject. It often happens that no amount of persuasion will accomplish the result and the State Board of Health is forced to resort to drastic methods. The broad powers of the State and even the Nation are at times insufficient to compel a community to purify its sewage. Like most health matters this question cannot ordinarily be handled by forcible methods. It is to be hoped that the time will come when fully aroused public opinion will no longer tolerate the defacement of nature by the careless disposal of sewage and when standards in this field of sanitary science will be as high, relatively speaking, as they now are in water purification.

INTERPRETATION OF WATER ANALYSES[1]

By J. W. Kellog[2]

In any attempt to interpret water analyses it is necessary, first, to know as much as possible about the origin of the sample, whether it be surface or ground water, the depth of the well, system of purification and other particulars.

The results may be considered under three divisions, as to the physical, chemical and bacterial properties of the water.

The physical properties of a water are to the average consumer of the greatest importance, and may often influence people to seek a clear sparkling polluted water in preference to that from the public supply which is safer, but has a less pleasing appearance.

In ground waters an increase over the normal in color or turbidity often indicates that surface water has gained entrance, either through faulty casings or leaky reservoirs. In surface waters the color or turbidity remaining in the treated water is one measure of the efficiency of filtration.

The chemical or mineral content of the natural waters of the State have very slight, if any, influence on the potability of the water. The latest investigations show that the hardness of a water has no deleterious effect on the human system (E. Sherman Chase, Journal, July, 1924). We have no hard waters in North Carolina, as hard waters are considered in the north and west. In relation to public health, the mineral content of a water has slight significance. In well waters an increase in the chlorides or nitrite content of a water may indicate pollution, but this increase is usually accompanied or often preceded by bacterial evidence of pollution. Natural waters in North Carolina are almost without exception alkaline. In water treatment plants, where alum is used as a coagulant, an overdose may result in acid water, the acid being free H_2SO_4, which is formed by the breaking down of the alum. If there is not sufficient natural alkalinity present, this

[1] Presented before the North Carolina Section meeting, November 12, 1924.

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acid should be neutralized by the addition of soda ash or hydrated lime, so that the water will give an alkaline reaction with erythrosine or lacmoid indicator. No water with an acid reaction should be turned into the distribution system. This lacmoid alkalinity corresponds very nearly to the temporary (carbonate) hardness. The true alkalinity is measured in terms of pH (H-ion concentration). This is the more accurate means of determining the proper balance of chemical dosage. By this method the alum and soda or lime may be evenly balanced in order to secure the optimum point of flocculation and thus keep to a minimum the amount of the residual soluble alum. It has been found that the optimum pH for securing the best floc varies with various waters, it being as low as 4.5 in some colored waters in eastern, and as high as 6.5 to 7.5 in some turbid waters, in western North Carolina, the average being from 5.5 to 6.5. The optimum for each water should be determined by the use of the jar test as described in the paper by Geo. F. Catlett in the JOURNAL, July, 1924. The amount of the residual soluble alum may be readily determined as described by Hatfield, in the Journal of Industrial Engineering Chemistry, March, 1924, a summary of which is given in the JOURNAL, July, 1924. With proper dosage, controlled by pH determinations and the jar test to secure the optimum "floc," this residual alum may be kept at a very low point, depending on the time of contact in the coagulation basin, the temperature and other factors. From a chemical standpoint the water which goes to the consumer should have an alkalinity of 8 to 12 p.p.m., a pH of not less than 6.8 and no residual alum. Under certain conditions the proper "floc" may have been obtained and passed through a filter which was not working properly, thus giving a precipitate of aluminum hydrate in the effluent. More often the hydrate in the effluent results from the soluble alum precipitating out after the water has passed the filter.

In the State Board of Health Laboratories plates are made of 1 cc. of each sample both on plain agar and lactose litmus agar. Both are incubated at 38°C. for twenty-four hours. The plain agar count is only an indication of the number of bacteria which will grow at that temperature and is ordinarily not the total number of bacteria per cubic centimeter. The lactose litmus agar count is usually lower than the plain agar count and its advantage is that it gives us an indication of the extent of existing pollution. The acid forming (lactose splitting) organisms, which are usually B. coli in water samples, grow luxuriantly on this medium and the pink or red colon-

ies are an index of the number of B. coli per cubic centimeter. The tests for B. coli are made on a special medium (lactose peptone broth bile mixture) which is an enrichment medium for the intestinal bacteria and which inhibits many of the ordinary water and soil organisms. Tests are made on 10, 1, 0.1 and 0.01 cc., etc., on raw water samples and on as many as five 10-cc. portions of the treated waters. The raw waters from moderately polluted streams show as many as 10, 100 or sometimes 1000 B. coli per cubic centimeter. In the filtered water the number falls to one in 10 cc. or one or two per 50 cc. The sterilization process should destroy these remaining sewage organisms, and leave a water which has no fermenting organisms in 50 cc. The U. S. P. H. standard for water to be used on interstate carriers for drinking purposes limits the number to no more than one B. coli per 100 cc. All purification plants at least should meet this standard. It is entirely possible, if proper attention is given to the filtration and sterilization processes. The regular use of the orthotoluidin test set will enable any operator to know that he is putting out a water which will pass these standards. Our experience shows that, in those plants where this test is made regularly and the dosage of chlorine is governed accordingly, we never receive a polluted sample, whereas in the plants where chlorination is done on the hit or miss basis or not governed by check tests, we often get a sample which shows several residual B. coli per 50 cc.

It should be mentioned that disease germs are not so nearly so widely distributed as the intestinal B. coli. This is one reason why we have never had a large water borne typhoid epidemic in the State. The presence of B. coli in water is undesirable and is an indication of the potential danger of the supply, not that the water is actually dangerous, unless it has been infected with the discharges from a previous case of typhoid or other water borne disease. Typhoid and dysentery germs originate only in a previous case of the disease, but they may be conveyed by water, milk or other secondary carrier.

FILTRATION PLANT CENSUS, 1924[1]

Water Filtration Plants in the United States Supplying Water for General Public Uses and Having Capacities of One Million Gallons per Day or Over

SUMMARY

(Rapid Sand Filtration)

	STATE	CITIES HAVING PLANTS	TOTAL INSTALLED CAPACITY M. G. D.	TOTAL POPULATION SERVED
1	Alabama	13	35.9	294,000
2	Arizona	0	0	0
3	Arkansas	11	28.0	145,000
4	California	7	68.9	607,000
5	Colorado	2	88.0	212,000
6	Connecticut	2	7.0	37,000
7	Delaware	1	12.0	52,000
8	Florida	3	27.0	115,000
9	Georgia	13	85.5	460,000
10	Idaho	1		8,000
11	Illinois	35	130.9	607,000
12	Indiana	18	90.7	437,000
13	Iowa	12	40.0	251,000
14	Kansas	14	66.1	266,000
15	Kentucky	14	108.3	444,000
16	Louisiana	5	49.0	470,000
17	Maine	6	20.6	100,000
18	Maryland	9	275.6	867,000
19	Massachusetts	1	14.0	110,000
20	Michigan	18	463.0	1,587,000
21	Minnesota	9	111.7	651,000
22	Mississippi	4	14.0	85,000
23	Missouri	14	207.3	998,000
24	Montana	5	26.9	57,000
25	Nebraska	1	1.5	6,000
26	Nevada	0	0	0
27	New Hampshire	0	0	0
28	New Jersey	19	172.0	1,204,000
29	New Mexico	0	0	0
30	New York	27	133.8	497,000
31	North Carolina	42	95.8	422,000
32	North Dakota	5	11.0	57,000
33	Ohio	45	743.3	2,957,000
34	Oklahoma	25	70.4	391,000
35	Oregon	4	8.0	34,000
36	Pennsylvania	78	319.1	1,643,000

[1] Compiled by C. G. Gillespie, Director, Bureau of Sanitary Engineering, California State Board of Health.

	STATE	CITIES HAVING PLANTS	TOTAL INSTALLED CAPACITY M. G. D.	TOTAL POPULATION SERVED
	(RAPID SAND FILTRATION—Continued)			
37	Rhode Island	4	13.0	66,000
38	South Carolina	15	50.0	244,000
39	South Dakota	3	11.6	50,000
40	Tennessee	13	53.3	353,000
41	Texas	23	100.5	594,000
42	Utah	0	0	0
43	Vermont	1	2.5	23,000
44	Virginia	25	147.3	665,000
45	Washington	7	11.5	30,000
46	West Virginia	22	99.0	361,000
47	Wisconsin	7	24.8	128,000
48	Wyoming	4	10.6	25,000
Totals		587	4,048.4	18,610,000
	(SLOW SAND FILTRATION)			
1	Colorado	4	33.5	90,000
2	Connecticut	3	31.0	329,000
3	Delaware	1	10.0	68,000
4	District of Columbia	1	70.0	454,000
5	Indiana	1	30.0	360,000
6	Maine	3	8.5	38,000
7	Massachusetts	7	40.0	421,000
8	New Hampshire	2	3.5	20,000
9	New York	12	56.7	342,000
10	Pennsylvania	7	604.2	2,564,000
11	Rhode Island	1	18.0	295,000
12	South Carolina	1	1.5	4,000
13	Vermont	1	2.5	7,000
14	Virginia	1	2.0	12,000
15	Wisconsin	2	4.6	51,000
Totals	Slow	47	916.0	5,054,000
	Rapid	587	4,048.4	13,610,000
Totals (rapid and slow)		634	4,964.4	23,664,000

WATER FILTRATION PLANTS IN THE UNITED STATES HAVING A CAPACITY OF 1 M.G.D. OR OVER

(Data supplied by State Departments of Health, 1924)

RAPID SAND FILTERS

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M. G. D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Alabama. Information furnished by G. H. Hazlehurst, Chief Sanitary Engineer					
Albany-Decatur	Tennessee River	2.0	12,404	1910	Chlorinated
Alexander City	Elkahatchee Creek	1.0	2,293	1923	Chlorinated
Birmingham	Village Creek and Cahaba River	20.0	178,806	1906	Chlorinated
Cordova	Warrior River	1.2	1,700[2]		Chlorinated
Cherokee Bluff	Tallapoosa River	1.2	600[2]	1924	Chlorinated
Fairfax	Chattahootchee	1.0	1,063	1915	Chlorinated
Florence	Tennessee River	1.0	10,529	1917	Chlorinated
Gadsden	Coosa River	2.0	14,737	1910	Chlorinated
Lanett	Chattahootchee	1.0	4,976	1923	Chlorinated
Montgomery	Alabama River	1.0	43,646	1913	Chlorinated
Opelika	Creek	1.0	4,960	1911	Chlorinated
Talladega	Talladega Creek	1.5	6,546	1923	Chlorinated
Tuscaloosa	Black Warrior	2.0	11,996	1914	Chlorinated
Arizona. None					
Arkansas. Information furnished by W. A. Selle, Assistant Engineer					
Batesville	White River	1.0	4,299	Under construction	
Camden	Cuachita River	1.0	3,238	1915	Pressure filters
Conway	Cadron	1.5	4,564	1923	Chlorinated
Fayetteville	White River	1.0	5,362	1916	Chlorinated
Fort Smith	Poteau River	5.0	28,870	1913–22	Chlorinated
Hot Springs	Creek	1.5	11,695	1912 and 1922	Chlorinated
Little Rock	Arkansas River	12.0	65,142	1891–97–1924	Chlorinated
Newport	White River	1.0	3,771	1923	Chlorinated
Russellville	Little Illinois River	1.0	4,505	1922	Chlorinated
Texarkana	Shallow wells	1.5	8,257		Pressure filters
Van Buren	Lees Creek	1.5	5,224	1924	
California. Information furnished by C. G. Gillespie, Director, Bureau of Sanitary Engineers.					
Eureka	Elk River	1.5	12,923[3]	1891–95, 1910–17	Chlorinated
Oakland (East Bay Water Company)	Lake Chabot	5.5	90,000[3]	1891	Chlorinated
	San Pablo Reservoir	12.0	180,000[3]	1920	Chlorinated
Presidio (San Francisco)	Wells	1.5	10,000[3]	1911	Chlorinated
	Lobos Creek	2.4	14,000[3]	1910–12	Chlorinated
Sacramento	Sacramento River	32.0	80,000[3]	1924	Chlorinated
San Diego	Reservoirs	10.0	100,000[3]	1906–15	Chlorinated
San Francisco	Lake Merced	2.5	100,000[3]	1912	Chlorinated
Santa Cruz	San Lorenzo River	1.5	20,000[3]	1923	Chlorinated

[2] Industrial.

[3] Estimated present population.

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M. G. D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.,)
Colorado. Information furnished by Dana E. Kepner, Sanitary Engineer					
Denver	South Platte River	22.0 64	207,500[3]	Under construction	Chlorinated
Rocky Ford	Arkansas River	2.0	4,000[3]		Chlorinated and softened
Connecticut. Information furnished by J. Frederick Jackson, Director, Bureau of Sanitary Engineering.					
Greenwich (Supplies part Chester, N. Y.)	Impounding reservoirs	5.0	30,000[3]	1887–1909	Pressure filters
Putnam	Natural lake	2.0	7,000[3]	1923	Gravity filters chlorinated.
Delaware. Information furnished by R. C. Beckett, Sanitary Engineer					
Wilmington	Brandywine Creek	12.0	51,500[3]	1916	Both rapid and slow sand filter plants are used daily. Rapid supplies 6 m.g.d. and slow about 8 m.g.d.
Florida. Information furnished by George W. Simons, Jr., Chief Sanitary Engineer					
Orlando	Lake	6.0	20,000[3]		
Tampa	River	15.0	80,000[3]	Under construction	
West Palm Beach	Lake	6.0	15,000[3]		
Georgia. Information furnished by H. C. Woodfall, Chief Engineer.					
Athens	River	3.5	16,748	1909–12	Gravity and pressure
Atlanta	River	42.0	250,000	1887–1910	
Augusta	River	10.0	52,548	1889–1912	
Carrollton	Creek	1.25	4,363	1905	
Cartersville	River	1.0	4,350	1912	
Columbus	River	6.0	31,125	1903–12	
Elberton	Creek	1.5	6,475	1904	
Jackson	Creek	1.0	2,027		
La Grange	Creek	2.0	17,038		
Macon	River	12.0	52,995	1898–1916	
Newman	Creek	1.0	7,037		
Rome	River	2.0	13,252	1908–12	
West Point	River	2.25	2,138	1902	
Idaho. Information furnished by W. V. Leonard, State Chemist					
Twin Falls	Snake River		8,324		Chlorinated
Illinois. Information furnished by Harry F. Ferguson, Chief Sanitary Engineer.					
Alton	Mississippi River	5.0	24,682	1898–1915	Chlorinated
Anna State Hospital	Reservoir	1.0	1,712	1913	Chlorinated
Cairo	Ohio River	3.0	15,203	1887–1901	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Illinois—Continued					
Champaign–Urbana	Wells	2.5	26,117	1913	Chlorinated
Charleston	Reservoir	1.0	6,615	1912	Chlorinated
Danville	Reservoir	7.0	33,776	1902–21	Chlorinated
Decatur	Reservoir	9.0	43,818	1913	Chlorinated
East St. Louis	Mississippi River	27.3	117,247	Part 1918	Chlorinated
Elgin	Fox River (emergency)	2.3	27,454	1887	Chlorinated
Evanston	Lake Michigan	12.0	37,234	1914–24	Chlorinated
Fort Sheridan	Lake Michigan	1.5		1913–19	Chlorinated
Freeport	Drift and rock wells	4.	19,669	1903–13	Chlorinated
Gillespie	Reservoir	1.0	4,063	1924	
Great Lakes (N. T. S.)	Lake Michigan	6.0		1915–17–18	Chlorinated
Hamilton	Reservoir	1.0	1,698	1912	Chlorinated
Herrin	Reservoir	1.0	10,986	1915	Chlorinated
Hinsdale	Wells	1.0	4,042	1915	
Jacksonville	Reservoir	2.1	15,713	1920–22	Chlorinated
Johnston City	Reservoir	1.0	7,137	1922	Chlorinated
Kankakee	Reservoir	4.4	16,753	1901	Chlorinated
Lawrenceville	Embarrass River	1.0	5,080	1910–16	Chlorinated
Macomb	Reservoir	1.0	6,714	1911	Chlorinated
Marion	Reservoir	1.16	9,582	1921	Chlorinated
Moline	Mississippi River	5.0	30,734	1902–11	Chlorinated
Mt. Carmel	Wabash River	1.5	7,456	1911	Chlorinated
Mt. Vernon	Reservoir	1.5	9,815	1912	Chlorinated
Murphysboro	Big Muddy River	2.0	10,703	1908–15	Chlorinated
Pana	Reservoir	1.0	6,122	1912	Chlorinated
Paris	Reservoir	2.0	7,985	1922	
Pontiac	Reservoir	1.5	6,664	1902–21	Chlorinated
Quincy	Mississippi River	6.0	35,978	1914–19	Chlorinated
Rock Island	Mississippi River	6.0	35,177	1910	Chlorinated
Rock Island Arsenal	Mississippi River	1.5			Chlorinated
Streator	Reservoir	3.6	14,779	1889–96, 1909	
Winnetka	Lake Michigan	3.0	6,694	1922	Chlorinated
Indiana. Information furnished by L. A. Geupel, Director, Water & Sewage Dept.					
Anderson	White River	8.0	40,000[3]	1904–16	
Aurora	Ohio River	1.0	4,299[3]	1904	
Columbus	Driftwood River	4.0	9,000[3]	1912	
East Chicago	Lake Michigan	8.0	45,000[3]		
Evansville	Ohio River	18.0	100,000[3]	1910	
Jasper	Patola River	1.0	3,000[3]	1916	
Logansport	Eel River	8.0	21,000[3]	1913	
Mt. Vernon	Ohio River	2.0	5,500[3]	1913	
Muncie	White River	5.0	45,000[3]		
New Albany	Ohio River	4.0	23,000[3]	1916	
Princeton	Patola River	2.25	7,500[3]	1915	
Seymour	White River	2.0	8,000[3]	1905	
Terre Haute	Wabash River	11.0	70,000[3]	1890–1900	
Valparaiso	Flint Lake	2.0	10,000[3]	1907	
Vincennes	Wabash River	5.0	18,000[3]	1890	
Warsaw	Center Lake	1.5	6,000[3]	1896	
Washington	White River	4.0	10,200[3]	1906	
Whiting	Lake Michigan	4.0	12,000[3]		

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Iowa. Information furnished by H. V. Pedersen, Civil and Sanitary Engineer.					
Burlington	Mississippi River	5.0	24,057	1905	
Cedar Rapids	Cedar River	8.0	45,566	1912	
Clarinda	Nodaway River	1.0	4,511		
Council Bluffs	Missouri River		36,162		
Creston	Impounding reservoir	2.0	8,034	1893	
Davenport	Mississippi River	9.0	56,727	1891–1908	
Fairfield	Impounding reservoir	1.0	5,948	1911	
Fort Madison	Mississippi River	3.0	12,066	1916	
Iowa City	Iowa River	2.0	11,267	1909	
Keokuk	Mississippi River	3.5	14,423	1893	
Oskaloosa	Skunk River	1.5	9,427	1902	
Ottumwa	Des Moines River	4.0	23,003	1911	
Kansas. Information furnished by J. L. Barron, Assistant Engineer					
Chanute	River	2.0	11,000[a]	1914	
Coffeyville	River	4.0	18,000[a]	1913	
Eldorado	River	1.6	11,000[a]		
Emporia	River	3.0	11,500[a]	1915	
Herington	Impounding reservoir	1.0	4,100[a]		
Horton	Impounding reservoir	1.0	4,000[a]	1912	
Kansas City	River	30.0	101,000[a]	1910	
Lawrence	River	4.0	15,000[a]		Softening
Manhattan	River	2.0	8,000[a]		Softening and iron removal
Marysville	River	1.25	3,000[a]	1914	
Osawatomie	River	1.0	4,800[a]	1915	
Ottawa	River	2.3	9,000[a]		
Parsons	River	5.0	16,000[a]		
Topeka	River	8.0	50,000[a]		Softening
Kentucky. Information furnished by F. C. Dugan, Director, Bureau of Sanitary Engineering					
Ashland	Ohio River	6.0	20,000[a]		
Catleffsburg	Ohio River	3.0	15,000[a]		
Cynthiana	Licking River	1.5	3,000[a]		
Danville	Dix River	4.5	10,000[a]	1905	
Frankfort	Kentucky River	6.0	12,000[a]	1912	
Harrodsburg	Salt River	1.0	3,000[a]		
Henderson	Ohio River	6.0	17,000[a]	1916	
Lexington	Impounding reservoir	8.0	50,000[a]	1895	
Louisville	Ohio River	60.0	275,000[a]	1905–14	
Morganfield	Ohio River	1.0	2,000[a]		
Mt. Sterling	Little River	1.0	3,000[a]	1912	
Paducah	Ohio River	6.0	20,000[a]	1904	
Paris	Stoner Creek	1.25	7,000[a]	1905	
Winchester	Impounding reservoir	3.0	7,000[a]	1904	
Louisiana. Information furnished by John H. O'Neill, Sanitary Engineer					
Houma	Bayou Black	1.0	5,400[a]		
Morgan City	Atchafalaya	1.0	5,500[a]	1912	
New Orleans	Mississippi River	40.0	410,000[a]	1909	

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M. G. D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Louisiana—Continued					
Shreveport	Red River	6.0	47,000[3]	1899–1916	
Westwego	Mississippi River	1.0	2,000[3]		
Maine. Information furnished by Elmer W. Campbell, Director, Division of Sanitary Engineering					
Bangor	Penobscot River	8.0	25,500[3]	1912	
Belfast	Little River	1.1	5,000[3]	1914	
Biddeford	Saco River	5.0	26,000[4] 50,000[5]	1910	
Calais	St. Croix River	2.0	7,000[3]		Auxiliary supply only
Kennebunk	Brook	2.0	5,000[3]	1915	Pressure filter
Old Town	Penobscot River	2.5	7,000[3]	1901	Pressure filter
Maryland. Information furnished by Abel Wolman, Chief Engineer					
Avalon	Patapsco River	2.5	30,000	1910–14	Combined rapid and slow sand filters
Baltimore City	Gunpowder River	128.0 100.0	733,826	1914	
Camp Meade	Patuxent River	2.5			(Government reservation)
Cumberland	Evitts Creek	12.0	29,837	1913	
Hagerstown	Antietam Creek	4.35	28,064	1912	Present.
	Potomac River	10.0			To be built. Both auxiliary to mountain supply
Havre de Grace	Susquehanna River	1.0	4,377	1906	
Luke	Potomac River	8.0	950		
Westport	Patapsco River	2.5			
Washington Suburban Sanitary District			40,000[3]	1925	
Burnt Mills	Northwest branch of Anacostia River	2.5			
Hyattsville	Northwest branch of Anacostia River	1.0			
Takoma Park	Sligo Branch	1.25			Temporarily abandoned. Held in reserve
Massachusetts. Information furnished by X. H. Goodnough, Chief Engineer					
Cambridge	Reservoirs	14.0	109,694		
Michigan. Information furnished by Edward D. Rich, Director					
Adrian	Wolf Creek	3.0	11,878	1898	
Alpena	Thunder Bay (Lake Huron)	3.0	11,100	1923	
Bay City	Saginaw Bay (Lake Huron)	20.0	47,554	Under construction	
Benton Harbor	Wells	2.0	12,233	1923	Softening plant

[4] Estimated present population in winter.
[5] Estimated present population in summer.

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Michigan—Continued					
Dearborn	Rouge River	2.0	3,000	1915	
Detroit	Detroit River	320.0	1,160,000	1923	
Escanaba	Bay De Noc (Lake Michigan)	6.0	15,100	1909	
Flint	Flint River	28.0	91,600	1913	
Flat Rock	Huron River	1.0		1923	
Grand Rapids	Grand River	48.0	137,634	1913	Softening plant
Highland Park	Lake St. Clair	10.0	46,500	1920	
Iron Mountain	Lake Antoine	3.0	10,000	Under construction	
Kingsford	Menominee River	1.0	1,000	1923	
Menominee	Green Bay (Lake Michigan)	3.0	8,907	1917	
Monroe	Lake Erie	4.0	11,573	1924	
Trenton	Detroit River	2.0	1,682	1924	
Wayne	Rouge River	1.0	1,900	1921	
Wyandotte	Detroit River	6.0	15,650	1920	
Minnesota. Information furnished by H. A. Whittaker, Director, Division of Sanitation					
Breckenridge	Ottertail River	1.0	2,401	1910	
Chisolm	Monroe Mine	2.0	7,039	1906–14	
Crookston	Red Lake River	1.0	6,825	1911	
East Grand Forks	Red Lake River	1.0	2,490	1909	
Ely	Long Lake	1.7	4,902	1904	
Eveleth	St. Mary's Lake	2.0	7,205		
Minneapolis	Mississippi River	60.0	380,582	1911	
St. Paul	Mississippi River, lakes and wells	42.0	235,000		
Thief River Falls	Red Lake River	1.0	4,685		
Mississippi. Information furnished by H. A. Kroeze, Director, Bureau of Sanitary Engineering					
Columbus	Luxapallila River	2.0	10,501	1899–1907	
Jackson	Pearl River	6.0	33,000	1915	
Meridian	Spring and impounding reservoirs	3.0	23,399		
Vicksburg	Mississippi River	3.0	18,072	1904	
Missouri. Information furnished by George W. Putnam, State Sanitary Engineer					
Chillicothe	Grand River (North)	1.21	6,772	1915	
Excelsior Springs	Wells	1.0	4,165	1914	Iron removal
Hannibal	Mississippi River	7.0	19,306	Under construction	
Joplin	Shoal Creek	6.0	29,902		
Kirksville	Chariton River	1.0	7,213		
Kirkwood	Meramec River and wells	2.5	4,422		Iron removal and softening plant
Louisiana	Mississippi River	1.3	4,060	1888–89	
Moberly	Impounding reservoir	2.0	12,808		
North Kansas City	Wells	1.0	870	1913	Iron removal

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Missouri—Continued					
St. Joseph	Missouri River	13.8	77,939	1898	
St. Louis	Mississippi River	160.0	772,897	1914	
Sedalia	Impounding reservoir	3.0	21,144		
Springfield	Spring and wells	6.0	29,631	1910	
Trenton	Thompson Fork	1.5	6,551	1916	
Montana. Information furnished by H. B. Foote, Director, Division. Water and Sewage					
Billings	Yellowstone River	6.5	15,100	1915	
Glendive	Yellowstone River	2.0	3,800		
Great Falls	Missouri River	12.0	24,100	1916	
Livingston	Yellowstone River	3.4	6,300		
Miles City	Yellowstone River	3.0	8,000	1910	
Nebraska. Information by L. O. Vose, State Bacteriologist					
Nebraska City	Missouri River	1.5	6,500	1891–1922	
Nevada. None					
New Hampshire. None					
New Jersey. Information furnished by Henry B. Costill, Director, Bureau of Engineering					
Ashbury Park	Wells	2.0	5,800	1895	Aeration and pressure filter, iron removal
Bound Brook Water Company	Surface	2.0	6,000	1913	Pressure and chlorinated
Bridgeton	Surface	3.0	14,000	1913	Chlorinated
Burlington	Surface	4.0	9,000	1910	Chlorinated
Elizabethtown Water Company	Surface	2.0	16,000		Chlorinated
Gloucester	Wells	3.0	12,000	1904	Aeration iron removal
Hackensack Water Company	Surface	37.0	400,000		Chlorinated
Merchantville Water Company	Wells	2.5	11,375	1911	Aeration pressure filter, iron removal
Middlesex Water Company	Surface	6.0	17,507		Pressure filters chlorinated
Mammouth Water Company	Surface and wells	2.0	28,420		Lime pressure filters, iron removal
Millville	Wells	1.0	4,250		Aeration pressure filters iron removal
New Brunswick	Surface	8.0	33,000	1916	Iron removal
Passaic Consolidated Water Company	Surface	44.0	421,000		
Perth Amboy	Wells	12.0	42,000		Aeration iron removal
Rahway	Surface	3.0	11,000	1907–10	Pressure filters chlorinated
Salem	Surface	1.0	7,500		Chlorinated
Somerville Water Company	Surface	2.5	11,000		Pressure filters chlorinated
Tintern Manor Water Company	Surface	7.0	34,000		Pressure filters chlorinated
Trenton	Surface	30.0	120,000	1914	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
New Mexico. None					
New York. (*Note*: No report received from New York State. The following list is taken from an article "Rapid Sand Filtration" by Geo. A. Johnson in Journal N. E. W. W. A., September, 1917.)					
Albion		1.0	4,683	1914	
Batavia		3.0	13,541	1916	
Binghamton		17.0	66,800	1902–13	
Brockport		2.5	2,980	1905–13	
Brooklyn		8.0	65,000	1903	
Cohoes		8.0	22,987	1910	
Elmira		7.0	45,393	1897	
Green Island		1.0	4,411	1902	
Hornell		3.0	15,025	1899–1904	
Ithaca		3.5	17,004	1903	
Kingston		6.0	26,688	1892–1902	
Lyons		1.0	4,253	1915	
Middletown		5.0	18,420	1900–09	
Niagara Falls		26.0	50,760	1910–12	
North Tarrytown		3.0	5,927		
Norwich		3.0	8,268	1904–07	
Oneonta		3.0	11,582	1906	
Rensselaer		4.0	10,823	1901	
Riverhead		1.0	2,750	1914	
Rochester		4.8	32,000		
Seneca Falls		2.0	6,389	1912	
Sonyea		1.0	1,500	1915	
Tarrytown		2.5	5,807		
Walton		1.5	3,598	1914	
Waterford		2.0	2,637	1914	
Watertown		10.0	31,285	1902	
Watervliet		4.0	16,073	1915	
North Carolina. Information furnished by H. E. Miller, Director, Bureau of Sanitary Engineering and inspection					
Albemarle	Long Creek	1.0	2,921	1913	Chlorinated
Badin	Yadkin River	1.0			Chlorinated
Burlington	Stony Creek	3.0	6,408		Chlorinated
Canton	Impounded mountain stream	1.0		1915	Pressure filters chlorinated
Charlotte	Catawba River	8.33	51,288	1896–1905	Chlorinated
Concord	Cold Water Creek	1.5	10,375	1911	Chlorinated
Cramerton	Creek	1.0			Chlorinated
Dunn	Cape Fear River	1.0			Chlorinated
Durham	Flat River	4.5	23,100	1916	Chlorinated
Elizabeth City	Knobbs Creek	1.0	9,130	1906	Chlorinated
Fayetteville	Little Cross Creek	2.0	9,612	1911	Chlorinated
Gastonia	Long Creek	2.0	15,711	1900–08	Chlorinated
Goldsboro	Little River	2.0 1.0	13,371	1913	Chlorinated
Greensboro	Reedy Fork	6.0	35,000	1903	Chlorinated
Greenville	Tar River	1.5	6,442	1905–13	Chlorinated
Hamlet	Marks Creek	1.5	7,115		Chlorinated
Henderson	Sandy Creek	1.0	5,509	1912	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
North Carolina—Continued					
Hickory	Henry's Fork	1.0	5,485		Chlorinated
High Point	Deep River	3.0	20,000	1893–1911	Chlorinated
Laurinburg	Jordan's Creek	1.0			Chlorinated
Lexington	Abbott's Creek	3.0	5,691		Chlorinated
Louisburg	Tar River	1.0	2,026	1905	Chlorinated
Lumberton	Lumber River	1.0	2,875	1916	Chlorinated
Moncure	Cape Fear River	1.0			Chlorinated
Mooresville	Byer's Creek	1.0			Chlorinated
Mt. Airy	Springs	1.0	6,014	1913	Chlorinated
Newton	Hildebran Creek	1.0	3,302		Chlorinated
No. Wilkesboro	Reddies River	1.0	2,547		Chlorinated
Proximity	Buffalo Lake	2.0	8,500		Chlorinated
Raleigh	Walnut Creek	6.0	26,500	1887–1913	Chlorinated
Reidsville	Big Troublesome Creek	1.0	5,535	1913	Chlorinated
Salisbury	Yadkin River	3.0		1916	Chlorinated
Sanford	Letts Creek	1.0	4,176	1907	Chlorinated
Shelby	French Broad River	1.0	3,803	1911	Chlorinated
South Pines	Springs	1.0	823	1910	Chlorinated
Statesville	North Fork Fourth Creek	1.5	9,215	1912	Chlorinated
Tarboro	Tar River	1.0	4,130	1911	Chlorinated
Washington	Tranter's Creek and wells	1.0	6,355	1914	Chlorinated
Weldon	Roanoke River	1.0	1,861	1913	Chlorinated
Wilmington	Cape Fear River	6.0	36,392	1906–09	Chlorinated
Wilson	Contentnea Creek	3.0	12,172	1916	Chlorinated
Winston-Salem	Frazier Creek	12.0	58,650	1904–10	Chlorinated
North Dakota. Information furnished by A. A. Whittemore, State Health Officer					
Bismarck	Missouri River pumping capacity	3.0	7,122	1924	
Fargo	Red River	4.0	21,961	1911	
Grand Forks	Red River	2.0	14,010	1910	
Minot	Maure River	1.0	10,476	1910	
Wahpeton	Red River	1.0	3,069	1914	
Ohio. Information furnished by F. H. Waring, Principal Assistant Engineer, Ohio State Board of Health					
Akron	Cuyahoga River (impounding)	50.0	200,000[3]	1915	
Alliance	Mahoning River	12.0	25,000[3]	1913	
Ashland	Jerome Creek (impounding)	1.5	10,500[3]	1921	
Ashtabula	Lake Erie	6.0	24,000[3]	1909	Chlorinated
Barberton	Wolf Creek (impounding)	4.0	20,000[3]	Under construction	
Bellaire	Ohio River	4.0	16,000[3]	1908	Softening, chlorinated
Bucyrus	Sandusky River tributary	2.3	11,000[3]	1905	Chlorinated
Cambridge	Wills Creek (storage reservoir)	3.0	14,000[3]	1917	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Ohio—Continued					
Cincinnati	Ohio River	112.0	438,000[3]	1907	
Cleveland:					
Division Avenue	Lake Erie	150.0	1,000,000[3]	1917	
Baldwin	Lake Erie	165.0		Under construction	
Columbus	Scioto River impounding	30.0	266,000[3]	1908	Softening, chlorinated
Conneaut	Lake Erie	2.9	10,000[3]	1900	Chlorinated
Defiance	Maumee River	2.2	10,000[3]	1921	Softening
Delaware	Olentangy River	2.0	8,700[3]	1922	Softening
Dennison	Big Stillwater Creek	3.9	13,000[3]	1904	Chlorinated
East Liverpool	Ohio River	6.0	22,000[3]	1918	
East Portsmouth	Ohio River	2.2	1,600[3]	1912	
East Youngstown	Lake Hamilton	1.0	13,000[3]	1917	
Elyria	Lake Erie	8.0	24,700[3]	1903–22	Chlorinated
Greenville	Greenville Creek	2.3	7,500[3]	Under construction	Softening
Huron	Lake Erie	1.0	1,700[3]	1909	
Ironton	Ohio River	4.0	14,500[3]	1920	
Lima	Lima Lake and Lost Creek	8.0	45,000[3]	1919	
Lorain	Lake Erie	10.0	41,000[3]	1897–1907	Chlorinated
Marietta	Ohio River	4.0	16,000[3]	1901	Chlorinated
Medina	West Branch of Rocky River	1.0	3,700[3]	1917	
Napoleon	Maumee Rive	1.0	4,200[3]	1916	
Newark	Licking River	6.0	27,000[3]	1901–1924	Softening, chlorinated
Niles	Mahoning River	3.0	15,000[3]	1917	Chlorinated
Painesville	Lake Erie	4.5	13,300[3]	1914	Chlorinated
Piqua	Miami River	5.0	15,800[3]	Under construction	Softening
Port Clinton	Lake Erie	1.5	4,300[3]	1912	Chlorinated
Portsmouth	Ohio River	8.0	44,000[3]	1914	Chlorinated
Ravenna	Muzzy Lake	3.0	8,000[3]	1919	
Sandusky	Sandusky Bay, Lake Erie	10.0	24,000[3]	1904	Chlorinated
Sebring	Mahoning River	1.5	4,200[3]	1923	
Steubenville	Ohio River	6.0	31,000[3]	1915	Chlorinated
Struthers	Burgess Lake	1.0	7,600	1924	
Tiffin	Sandusky River	1.5	15,500[3]	1915–19	Chlorinated
Toledo	Maumee River	56.0	280,000[3]	1910	Chlorinated
Toronto	Ohio River	2.0	4,900[3]	1924	
Upper Sandusky	Sandusky River	1.0	3,700[3]	1905	
Warren	Mahoning River	8.0	35,000[3]	1895–1917	
Willoughby	Chagrin River	1.0	3,000[3]	1914	Chlorinated
Youngstown	Mahoning River	25.0	160,000[3]	1905	Softening, chlorinated
Oklahoma. Information furnished by H. J. Darcy, Sanitary Engineer					
Altus	Impounding reservoir	2.0	4,500[3]	1916	
Bartlesville	Caney River	1.0	14,500[3]	1912	
Blackwell	Chickashia River	2.0	7,200[3]	1909	
Checotah	Canadian River	1.0	2,400[3]		

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Oklahoma—Continued					
Chickasha	Washita River	1.25	11,000[3]	1910	
Claremore	Verdi Gris River	1.0	3,500[3]	1911	
Cushing	Creek	2.0	10,000[3]		
Durant	Blue River	1.0	7,300[3]	1911	
Guthrie	Impounding reservoir	1.0	11,800[3]	1910	
Henryetta	Impounding reservoir and North Canadian River	1.5	6,000[3]	1916	
Hobart	Elk Creek	1.0	2,900[3]		
Lawton	Lake Lawtonka	5.0	8,900[3]		
McAlester	Bull Creek	3.0	13,000[3]		
Nowata	Verdi Gris River	1.5	4,500[3]		
Oklahoma City	Canadian River	16.0	115,000[3]	1906	
Okmulgee	Canadian River	4.0	17,500[3]		
Pawhuska	Bird Creek	1.0	6,500[3]	1907	
Pawnee	Black Bear Creek	1.5	2,500[3]		
Perry	Black Bear Creek	1.125	3,500[3]		
Poteau	Poteau River	1.0	2,700		
Sapulpa	Rock Creek	2.0	11,600[3]		
Shawnee	Canadian River	2.5	15,400[3]	1904	
Tulsa	Arkansas	14.0	100,000[3]		
Vinita	Grand River	2.0	5,000[3]		
Wagoner	Grand River	1.0	3,500[3]	1914	Pressure filters
Oregon. Information furnished by Frederick A. Strickin, Health Officer					
Albany	Santiam River	1.0	4,840	1912	
Arlington	Columbia River	1.0	529	1911	
Eugene	Williamette River	5.0	10,593	1906–11	
Salem	Williamette River	1.0	17,679		
Pennsylvania. Information furnished by W. L. Stevenson, Chief Engineer					
Beaver Valley	Beaver River	9.3	35,000	1892–1900–04–07	Chlorinated
Berwick	Susquehanna River	1.65	14,000	1914	Chlorinated
Bethlehem	Lehigh	10.0	32,600	1904–17	Chlorinated
Bloomsburg	Fishing Creek	3.0	7,500	1913	Chlorinated
Brackenridge	Allegheny River	3.0	9,000	1908	Chlorinated
Bristol	Delaware	2.0	9,500	1906–18	Chlorinated
Brookville	North fork of Red Bank Creek	1.0	3,000	1912	Chlorinated
Butler	Connoquennessing Creek and Thorn Run	5.0	25,000	1902–03–06	Chlorinated
Cairnbrook	Beaver Run	1.0	2,500		Chlorinated
Canonsburg	Spear Run and Little Chartier Creek	2.9	8,500	1910–11	Chlorinated
Carlisle	Conodoguinet Creek	1.25	12,000	1896	Chlorinated
Carrick	Monongahela River	14.2	118,000	1905	Chlorinated
Catasauqua	Mill Creek and Lehigh River	2.0	12,000	1914	Chlorinated
Charlerio	Monongahela River	5.0	32,000	1911–13	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Pennsylvania—Continued					
Chester	Delaware River	10.0	55,000	1903-08-20	Chlorinated
Coatesville	Rock Run	1.0	3,000	1918	Chlorinated
Columbia	Susquehanna River	2.0	10,500	1902	Chlorinated
Connelsville	Youghiogheny River and Laurel Run	2.8	15,500	1900-15	Chlorinated
Danville	North Branch of Susquehanna River	1.43	6,900	1905-13-16	Chlorinated
Danville State Hospital	North Branch of Susquehanna River	1.4	1,800	1903-05-09	Chlorinated
Elizabeth	Monongahela River	2.25	19,000	1901-1920	Chlorinated
Elwood City	Slippery Rock Creek	2.4	8,500	1910-19	Chlorinated
Erie	Lake Erie	24.0	104,000	1914	Chlorinated
Ernest	McKie's Run	1.0	1,950	1907	Chlorinated
Evitts	Evitts Creek	12.0	25,000	1913-18	Chlorinated
Franklin	French Creek	2.0	9,500	1908	Chlorinated
Freeport	Allegheny River	2.0	2,200	1909-20	Chlorinated
Gettysburg	Marsh Creek	1.0	4,300	1894-1912	Chlorinated
Greenville	Little Shenango River	1.5	8,000	1914	Chlorinated
Harrisburg	Susquehanna River	22.0	75,900	1905-23	Chlorinated
Hershey	Manada Creek	1.0	1,850	1915	Chlorinated
Hogsland	Delaware River	2.0	1,000	1918	Chlorinated
Hummelstown	Swatara Creek	2.0	10,000	1909	Chlorinated
Huntington (School)	Juaniata River	1.0	900	1913	Chlorinated
Indiana	Two Lick Creek	1.26	6,900	1908	Chlorinated
Jenkintown	Pennypack Creek	1.5	3,000	1910	Chlorinated
Jersey Shore	Larry Creek	1.0	6,500	1917	Chlorinated
Johnsonburg	Powers Run	1.0	4,100	1917	Chlorinated
Jonestown	Big Swatara Creek	3.0	12,600	1911	Chlorinated
Kittanning	Allegheny River	3.0	7,000	1905-22	Chlorinated
Lancaster	Conestoga Creek	9.0	55,000	1906	Chlorinated
Latrobe	Loyalhanna Creek	3.6	11,500	1914	Chlorinated
McDonald	St. Patrick's Run	1.0	4,000	1915	Chlorinated
McKeesport	Youghiogheny River and Monongahela River	6.6	67,500	1908	Chlorinated
Mechanicsburg	Yellow Breeches Creek	1.0	5,000	1909-20	Chlorinated
Media	Ridley Creek	1.0	5,000	1898	Chlorinated
Middletown	Swatara Creek and Iron Mine Run	1.0	4,000	1910	Chlorinated
Midland	Ohio River	1.0	5,400	1914	Chlorinated
Monongahela City	Monongahela River	2.0	10,000	1904	Chlorinated
Mount Union	Juniata River	3.0	250	1915	
Natrona	Allegheny River	1.0	5,500	1910-15-17	Chlorinated
New Castle	Shenango River	8.0	44,000	1898-1904-12	Chlorinated
New Cumberland	Yellow Breeches Creek	1.5	7,500	1912	Chlorinated
New Kensington	Allegheny River	3.0	15,000	1913	Chlorinated
Norristown	Schuylkill River	6.0	31,000	1901	Chlorinated
Oakmont	Allegheny River	3.0	10,000	1915-16	Chlorinated
Philadelphia Suburbs.	Pickering Creek	4.0	52,000	1911	Chlorinated
Philadelphia Suburbs.	Crum Creek	5.0	75,000	1896	Chlorinated
Phoenixville	Schuylkill River	3.0	13,000	1914	Chlorinated
Polk	North Sandy Creek	1.0	2,500	1918	Chlorinated

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Pennsylvania—Continued					
Pottstown	Schuylkill River	4.0	18,000	1909	Chlorinated
Punxsutawney	Clover Run and Mahoney Creek	2.0	10,000	1910	Chlorinated
Ridgway	Big Mill Creek	2.0	5,900	1908–15	Chlorinated
Royersford	Schuylkill River	2.0	6,000	1917	Chlorinated
Sayre	North Branch Susquehanna River	4.0	12,500	1904	Chlorinated
Scranton	Leggett Creek	6.0	25,000	1910	Chlorinated
Sharon	Shenango River	5.0	38,000	1900–03–16	Chlorinated
South Brownsville	Monongahela River	3.0	11,000	1916	Chlorinated
Spring Grove	West Branch of Codorus Creek and mountain stream	4.42	1,050	1895–1902	Chlorinated
Sunbury	Little Shamokin Creek Susquehanna River	8.0	15,900	1904–07–14–18	Chlorinated
Tarentum	Allegheny River	1.0	6,700	1914	Chlorinated
Vandergrift	Artesian wells	1.5	12,400	1897–1905–15	Chlorinated
Warren	Morrison Run and Allegheny River	3.0	12,000	1905	Chlorinated
Washington	Tributary Chartiers Creek	3.0	18,000	1902	Chlorinated
Waynesburg	South Fork of Little Ten Mile Creek and Brown's Creek	1.0	4,500	1902	Chlorinated
Wilkes-Barre	Toby Creek	6.5	70,000	1895	Chlorinated
	Crystal Lake	4.7	60,000	1895	Chlorinated
Wilkinsburg	Allegheny River	17.5	109,000	1910–17–18	Chlorinated
York	South Branch of Codorus Creek	9.0	58,000	1899	Chlorinated
Rhode Island. Information furnished by Stephen DeM. Gage, Chemist and Sanitary Engineer					
Barrington, Bristol, Warren	Reservoirs on Kickemuit River	3.0	22,600	1912	Chlorinated
E. Greenwich, Warwick[6]	Hunt's River	1.0	4,500	1908	Chlorinated
East Providence	Ten Mile River	3.0	9,000	1906–14	Chlorinated
Newport	Impounding reservoirs	6.0	30,000	1910	Chlorinated
South Carolina. Information furnished by E. L. Filby, Sanitary Engineer					
Anderson	Baileys Creek	1.0	11,000[3]	1910	Turbid, soft, chlorinated
Charleston	Impounding Goose Creek	14.0	70,000[3]	1902–09	Algae, very soft, chlorinated
Chester	Sandy Creek	1.0	6,000[3]	1909	Sandy, slightly turbid, chlorinated
Columbia	Congaree River	12.0	50,000[3]	1902–06	Very turbid, soft, chlorinated
Easley	Creek	1.0	4,000[3]		New plant, clear water, chlorinated
Gaffney	Creek	1.0	6,000[3]	1905	Soft, turbid, chlorinated

[6] Part of town only.

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
South Carolina—Continued					
Great Falls	Catawba	1.0	3,500[3]		Village, cotton mill, chlorinated
Greenville	Enoree River	3.0	30,000[3]		Turbid mountain water, chlorinated
Laurens	Creek	1.0	5,000[3]	1905	Turbid, sand, chlorinated
Lyman	Tiger River	6.0	5,000[3]		Village, cotton mill, chlorinated
Newberry	Creek	1.0	6,000[3]		Turbid, soft, chlorinated
Rock Hill	Catawba River	1.0	9,500[3]	1910	Turbid, soft, chlorinated
Spartanburg	3 small creeks	4.0	30,000[3]		Turbid, soft, chlorinated
Union	2 creeks	2.0	6,500[3]	1900	Turbid, soft, chlorinated
Ware Shoals	Saluda	1.0	2,000[3]		Village, cotton mill, chlorinated
South Dakota. Information furnished by A. H. Wieters, Director, Division of Sanitary Engineering					
Huron	James River	2.0	10,000[3]	1914	
Sioux Falls	Shallow wells	8.0	30,000[3]		Iron removal
Watertown	Lake Kampeska	1.6	10,000[3]		
Tennessee. Information furnished by Howard R. Fullerton, Director, Division of Sanitary Engineering					
Bristol	Springs	1.5	8,047	1924	
Chattanooga	Tennessee River	15.2	57,895	1888–93	
Clarksville	Cumberland River	1.5	8,110	1910	
Columbia	Duck River	1.0	5,526	1915	
Dyersburg	Deep wells and Forked Deer River	1.0	6,444	1904–07	
Greenville	Spring	1.0	3,775	1923–24	
Kingsport	Impounding reservoir	1.0	5,692		Chlorinated
Knoxville	Tennessee River	8.0	77,818	1904–14	
Memphis	Wells	19.0	162,351	1923–24	Iron removal
Morristown	Spring	1.0	5,875	1915	
Murfreesboro	Spring	1.0	5,367	1907	
Pulaski	Richland Creek	1.1	2,780	1921	
Shelbyville	Duck River	1.0	2,912		Chlorinated
Texas. Information furnished by V. M. Ehlers, State Sanitary Engineer					
Austin	Colorado River	8.0	35,000		
Beaumont	Neches River	8.0	41,000	1904	
Brownsville	Rio Grande River	2.0	12,000	1911	
Corpus Christi	Nueces River	2.0	11,000	1915	Pressure filters
Corsicana	Impounding reservoir	1.0	12,000		
Dallas	Impounding reservoir	26.0	160,000	1913	
Denison	Lake Shawnee	2.0	17,000	1914	
Breckenridge	Brazos River	2.0	2,000		
Fort Worth	Lake Worth	20.0	110,000	1911	
Jacksonville	Impounding reservoir	1.0	4,000		
Laredo	Rio Grande River	4.0	23,000	1910	
Longview	Sabine River	1.0	6,000	1915	

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Texas—Continued					
Marlin	Impounding reservoir	1.0	4,500		
Palestine	5 wells	2.0	11,500		
Paris	Impounding reservoir	2.0	15,000	1909	
Ranger	Impounding reservoir	2.0	16,500		
Robstown	Neuces River	1.0	1,000		
San Angelo	Concho River	2.5	10,000		Pressure filters
Sweetwater	Impounding reservoir	1.0	4,500		
Temple	Leon River	2.0	11,000	1911	
Terrell	Impounding reservoir	1.0	8,000		
Waco	Brazos River	5.0	39,000	1912	
Wichita Falls	Impounding reservoir	4.0	40,100	1904	
Utah. None					
Vermont.					
Burlington	Lake Champlain	2.5	22,779	1908	
Virginia. Information furnished by Richard Messer, Sanitary Engineer					
Alexandria	Creek	2.5	18,060		
Altavista	River	1.0	1,206		
Ashland	South Anna River	1.0	1,325		
Bristol	Creek	1.5	6,826		
Camp Humphries	Impounded	2.0	3,000		
Central State Hospital	Appomattox River	1.0	2,000		
Covington	Jackson River	3.0	5,900		
Culpeper	Creek	1.0	1,850		
Danville	Dan River	5.0	21,539	1905–15	
Fieldale	Smith River	2.0	261		
Front Royal	Creeks	1.14	1,404		
Hopeville	Appomattox and James Rivers	28.0	1,397		
Lynchburg	Pedlar River	6.0	30,070		
Newport News	Impounded	8.0	44,777	1906	
Norfolk	Lakes	15.7	115,777	1899	
Norfolk	Lake Prince	12.0	125,443		
Petersburg	Appomattox River	2.5	31,012	1901–10	
Pocahontas	Creek	1.0	2,700		
Portsmouth	Lakes Kilby and Cohoon	12.0	63,510	1907	
Quantico	Chippawamsic	2.0	2,000		
Radford	New River	1.0	4,627		
Schoolfield	Dan River	5.0	3,525		
Shenandoah (North and west)	Shenandoah River	2.0	300		
South Boston	Dan River	1.0	4,338	1916	
Richmond	River	30.0	171,667		
Washington. Information furnished by C. E. Dorisy, Sanitary Engineer					
Anacortes	Lake Campbell Lake Whistle	2.0	6,507	Under construction	
Arlington	Stilaguamish River	1.0	2,306	Under construction	

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Washington—Continued					
Kelso	Cowlitz River	2.0	6,500[7]		Pressure filters
Longview	3 wells	2.0	3,000[7]		Iron removal
Lynden	Nooksack River	1.0	1,511		
Mt. Vernon	Skagit	1.0[8]	3,525		Pressure filters used as gravity filters
Wenatche	Columbia River	2.5	6,324[9]		
West Virginia. Information furnished by E. S. Tisdale, Chief Engineer					
Benwood	Ohio River	1.5	6,000[3]	1900–06	
Bluefield	Spring supply	4.0	20,000[3]	1924	
Buckhannon	Buckhannon River	1.0	6,000[3]	1918	
Charleston	Elk River	12.0	50,000[3]	1911–20	
Clarksburg	West Fork River	9.0	40,000[3]	1911–20	
Elkins	Tygart Valley River	2.0	7,500[3]	1922	
Fairmont	Tygart Valley River	4.0	25,000[3]	1924	
Glenville	Little Kanawha River	1.0	1,200[3]	1924	
Hinton	Greenbrier River	1.0	6,000[3]	1917	
Huntington	Ohio River	10.0	60,000[3]	Enlarged 1923	
Kanawha City	Kanawha River	2.0	3,000[3]	1921	
Keyser	New Creek	2.0	9,000[3]	1924	
Logan	Guyan River	2.0	8,000[3]	1924	
Morgantown	Monongahela River	1.5	10,000[3]	1900, enlarged 1921–23	
Nitro	Kanawha	20.0	2,500[3]	Only portions being used, built during war for powder plan	
Shinnston	West Fork River	1.0	4,000[3]	1922	
Sistersville	Ohio River	1.0	4,000[3]	1916	
St. Albans	Kanawha River	1.0	4,000[3]	1922	
Weirton	Ohio River	1.0	6,000[3]	1921	
Weston	West Fork River	1.0	6,000[3]	1913	
Wheeling	Ohio River	20.0	75,000[3]	1924	
Williamson	Tug River	1.0	8,000[3]	1911	
Wisconsin. Information furnished by O. J. Muegge, Assistant Sanitary Engineer					
Appleton	Fox River	3.0	19,561	1912	Chlorinated
Kenosha	Lake Michigan	7.35	40,472		Chlorinated
Marinette	Green Bay	3.0	13,610	1899	Chlorinated
Merrill	Prairie River	1.66	8,068	1897	Chlorinated
Oshkosh	Lake Winnebago	5.56	33,162	1916	Chlorinated
Portage	Wisconsin River	1.5	5,582	Under construction	Chlorinated
South Milwaukee	Lake Michigan	2.58	7,598	1910	Chlorinated

[7] Estimated.
[8] 2.0 ultimate.
[9] Water from this source supplied also to a large number of residents out of the city limits.

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Wyoming. Information furnished by G. M. Anderson, M. D., State Health Officer					
Basin	Big Horn River	1.0	1,088	1922	
Cheyenne	Crow Creek	5.0	13,829	1915	
Green River and Rock Springs	Green River	2.3	2,140 6,456	1918	
Parco	North Platte River	2.3	1,000±	1918	

Slow Sand Filters

Colorado. Information furnished by Dana E. Kepner, Sanitary Engineer					
Denver	South Platte River	30.0	72,500[9]	1890	
Fort Collins	Poudre River	1.0	11,000[9]	1910	
Greeley	Poudre River	1.5		1906	
Loveland	Thompson River	1.0	6,000[9]		
Connecticut. Information furnished by J. Fredrick Jackson, Director, Bureau of Sanitary Engineering					
Hartford	Impounding reservoirs	16.0	151,000		
New Haven	Impounding reservoirs	12.0	162,537		Only part filtered
South Norwalk	Impounding reservoirs	3.0	15,000		
Delaware. Information furnished by R. C. Beckett, Sanitary Engineer					
Wilmington	Brandywine Creek	10.0	68,500		
District of Columbia. Information furnished by A. C. Daley, Asst. Superintendent, Filtration Plant					
Washington	Potomac River	70.0	454,026	1905	
Indiana. Information furnished by L. A. Geupel, Director, Water and Sewage Department					
Indianapolis	White River	30.0	360,000	1903	
Maine. Information furnished by Elmer W. Campbell, Director, Division of Sanitary Engineering					
Augusta		4.0	14,114	1914	
Bar Harbor	Eagle Lake	2.5	2,622[10] 15,000[11]		
Gardner	Cobbosseecontee Stream	2.0	9,000		
Massachusetts. Information furnished by X. H. Goodnough, Chief Engineer					
Brookline		5.0	37,748	1915	
Greenfield		1.0	15,482		
Lawrence	Merrimac River	6.0	94,270	1893–1907	
Lowell		10.0	112,759	1915	
Marblehead		2.0	7,324	1908	
Middleboro		1.0	8,453	1913	
Springfield	Westfield Little River	15.0	145,000	1906	

[10] Winter.
[11] Summer.

NAME OF TOWN	SOURCE OF SUPPLY	FILTER CAPACITY M.G.D.	POPULATION SUPPLIED (1920)	DATE INSTALLED	REMARKS (CHLORINATED, ETC.)
Washington—Continued					
Kelso	Cowlitz River	2.0	6,500[7]		Pressure filters
Longview	3 wells	2.0	3,000[7]		Iron removal
Lynden	Nooksack River	1.0	1,511		
Mt. Vernon	Skagit	1.0[8]	3,525		Pressure filters used as gravity filters
Wenatche	Columbia River	2.5	6,324[9]		
West Virginia. Information furnished by E. S. Tisdale, Chief Engineer					
Benwood	Ohio River	1.5	6,000[8]	1900–06	
Bluefield	Spring supply	4.0	20,000[8]	1924	
Buckhannon	Buckhannon River	1.0	6,000[8]	1918	
Charleston	Elk River	12.0	50,000[8]	1911–20	
Clarksburg	West Fork River	9.0	40,000[8]	1911–20	
Elkins	Tygart Valley River	2.0	7,500[8]	1922	
Fairmont	Tygart Valley River	4.0	25,000[8]	1924	
Glenville	Little Kanawha River	1.0	1,200[8]	1924	
Hinton	Greenbrier River	1.0	6,000[8]	1917	
Huntington	Ohio River	10.0	60,000[8]	Enlarged 1923	
Kanawha City	Kanawha River	2.0	3,000[8]	1921	
Keyser	New Creek	2.0	9,000[8]	1924	
Logan	Guyan River	2.0	8,000[8]	1924	
Morgantown	Monongahela River	1.5	10,000[8]	1900, enlarged 1921–23	
Nitro	Kanawha	20.0	2,500[8]	Only portions being used, built during war for powder plan	
Shinnston	West Fork River	1.0	4,000[8]	1922	
Sistersville	Ohio River	1.0	4,000[8]	1916	
St. Albans	Kanawha River	1.0	4,000[8]	1922	
Weirton	Ohio River	1.0	6,000[8]	1921	
Weston	West Fork River	1.0	6,000[8]	1913	
Wheeling	Ohio River	20.0	75,000[8]	1924	
Williamson	Tug River	1.0	8,000[8]	1911	
Wisconsin. Information furnished by O. J. Muegge, Assistant Sanitary Engineer					
Appleton	Fox River	3.0	19,561	1912	Chlorinated
Kenosha	Lake Michigan	7.35	40,472		Chlorinated
Marinette	Green Bay	3.0	13,610	1899	Chlorinated
Merrill	Prairie River	1.66	8,068	1897	Chlorinated
Oshkosh	Lake Winnebago	5.56	33,162	1916	Chlorinated
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Delaware. Information furnished by R. C. Beckett, Sanitary Engineer					
Wilmington	Brandywine Creek	10.0	68,500		
District of Columbia. Information furnished by A. C. Daley, Asst. Superintendent, Filtration Plant					
Washington	Potomac River	70.0	454,026	1905	
Indiana. Information furnished by L. A. Geupel, Director, Water and Sewage Department					
Indianapolis	White River	30.0	360,000	1903	
Maine. Information furnished by Elmer W. Campbell, Director, Division of Sanitary Engineering					
Augusta		4.0	14,114	1914	
Bar Harbor	Eagle Lake	2.5	2,622[10] 15,000[11]		
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New Hampshire. (Geo. A. Johnson, in Journal N. E. W. W. A. September, 1917)					
Dover		2.0	13,250	1902	
Somersworth		1.5	6,700	1897	
New York. (Geo. A. Johnson, in Journal N. E. W. W. A. September, 1917)					
Albany	Hudson River	25.0	113,344	1899	
Brooklyn		1.0	10,000	1909	
Geneva		3.0	14,648	1911	
Hudson		2.5	11,745	1876	
Ilion		1.2	10,169		
Mechanicville		2.0	8,166		
Nyack		2.0	4,444	1899	
Ogdensburg		3.0	14,609	1912	
Peekskill		3.0	15,868	1909	
Poughkeepsie		3.0	35,000	1874	
Westfield		1.0	3,413		
Yonkers		10.0	100,176	1906	
Pennsylvania. Information furnished by W. L. Stevenson, Chief Engineer					
Apollo	Beaver River	2.0	7,000	1903	Chlorinated
Bethlehem	Lehigh River	4.0	12,000	1904	Chlorinated
Coatesville	Rock Run	2.25	9,000	1915	Chlorinated
Philadelphia	Schuylkill and Delaware River	368.0	1,823,779	1902	Chlorinated
Pittsburgh	Allegheny River	200 0	588,343	1908	Chlorinated
Reading	Several Creeks	25.0	110,000	1903–15	Chlorinated
Steelton	Susquehanna River	3.0	13,400	1907	Chlorinated
Rhode Island. Information furnished by Stephen De M. Gage, Chemist and Sanitary Engineer					
Providence	Pawtuxet River	18.0	295,000	1904	
South Carolina. Information furnished by E. L. Filby, Sanitary Engineer					
Georgetown	Black River	1.5	4,500[3]		Chlorinated
Vermont.					
St. Johnsbury	Stiles Pond	2.5	7,164	1897	
Virginia. Information furnished by Richard Messer, Sanitary Engineer					
Charlottesville	Reservoir	2.0	11,888		
Wisconsin. Information furnished by O. J. Muegge, Assistant Sanitary Engineer					
Ashland	Lake Superior	2.67	11,334	1895	
Superior	Lake Superior	1.95	39,624	1899	

RELATIONSHIP OF THE MASTER PLUMBER TO THE INDUSTRIAL DEVELOPMENT OF NORTH CAROLINA[1]

By M'Kean Maffitt[2]

The relationship of the master plumber to the development of the state is so completely interwoven with the relationship of the water works superintendent to the industrial development of the state that you can not differentiate between the two. The master plumber supervises the installation of all the piping and fixtures necessary for the use, and the carrying off, of the product of the water works system, that is, with the exception of the water used for fire protection. Therefore, without the plumbing system there would be small use for the water works system. In the smaller towns, with no plumbing and no fire protection, there would be no question of a water supply.

The two main ideas of the water and plumbing system are to furnish water for all domestic uses. The use of water-carriage is the most successful and most economical method of disposing of household wastes. The use of water from the old oaken bucket for domestic purposes has been replaced by the use of water from the spigot. The average household has water in profuse quantities at all times of the day for any and all purposes. This universal use of water makes it necessary that the water should be pure and free from contamination. While all of the water is not used for immediate personal uses and some of it could be of a lower purity than usually furnished, it would be too dangerous to have two water supplies in the house. There would be some chance of using the impure supply for the purposes for which the pure supply was intended. Thus we must have one supply that is pure enough for drinking and plentiful enough for use in flushing sewers, sprinkling lawns, washing clothes, scouring floors, etc. The master plumber has so developed the plumbing and house drainage system that we can afford to furnish pure water at all times for all uses. Were it not for the develop-

[1] Presented before the North Carolina Section meeting, November 13, 1924.

[2] Superintendent of Water and City Engineer, Wilmington, N. C.

ment of the plumbing system to where it is we could not furnish the necessary amount of water for all domestic uses with our present equipment. It might then become necessary to have two separate systems. The water mains act as the arteries of the two systems and carry the water to the user under pressure. The plumbing system acts as the capillary veins and distributes the water uniformly and evenly from the pressure side to the drainage side. The sewer system acts as the veins and carries off the water and the added impurities by gravity and without pressure. The relationship is so close that the water plant can not develop faster than the plumbing and sewer systems. One furnishes the water and the other carries it away. The master plumber is the middle-man through whom the superintendent has to deliver his goods.

A review of the industrial development of North Carolina may enable us to visualize the future. Judging from the past, the future holds much in store for us. So much so, that some times I fear the average water works will not be developed fast enough to keep pace with the industrial development. I see more plainly each day the growing need for the work that this Association is doing. When I see the great strides that this state has taken in the industrial world, I am impressed with the necessity of a bigger and better work by this organization. I know that without the aid that we can, and do, receive from this work we will never be able to keep pace with the marvelous growth of the state. This Association has a great and good work cut out for it in developing men of sufficient capacity to handle the ever-growing water works systems that the development of the state is going to make necessary.

REVIEW OF CONDITIONS AND DEVELOPMENT

The living conditions of the state in 1880 were such that there is no comparison with the living conditions of today. In 1880 there was hardly a water works system in the state, unless it was some small plant for fire protection for a manufacturing plant. The people used well water for all domestic purposes, and surface privies, with the resultant unsanitary conditions, for disposal of fecal matter. At this time the death rate was over 70 per 1000 population, whereas lately it has been about 12.5 per 1000 population. This means that there has been a reduction in the deaths in the state of about 34,500 per annum. In addition to this the number of workdays that have been saved to the people amount to 3,500,000 per annum. If we

value the deaths that would have been at $5000 each and the work days at $5.00 each, to say nothing of doctor's bills, medicine, nursing etc., etc., there has been saved to the state annually over $190,000,000. This saving of life, suffering and money is the result of better sanitary conditions, better medical attention, better living conditions and above all better and purer water. That is what your state board of health has helped to do. It is what your master plumber has helped to do. It is what you have helped to do. All of these agencies put together have made of North Carolina the state that buys less coffins and more baby carriages per capita than any other state in the union.

POPULATION

The per cent increase in population in the larger cities of the state for the past ten years has been as follows: Asheville, 51.9; Charlotte, 36.2; Wilmington, 29.6; and Winston, 113.2 per cent. The entire state increased from 2,206,287 to 2,559,123 or 16 per cent, thus showing that the urban is increasing faster than the rural population. This increase in urban population means that the water supplies have to increase at an even faster rate. As the population increases the water consumption increases at a greater rate, due to industrial uses. Has there been a like increase in the ability and capacity of the different superintendents? Are the men in charge of the smaller plants getting the training that they need to make them capable of handling the larger plants? We are increasing our membership at a faster rate than the state is advancing, but are we increasing our results faster than the demand for bigger and better results?

In 1900 the value of all property in North Carolina was $682,000,000 which had increased to $4,543,000,000 in 1922, an increase of 570 per cent. In 1900, the value of all property in the South was eighteen billion dollars which increased to over seventy-one billion in 1922, an increase of 300 per cent. The state increased nearly twice as fast as the entire South. In percentages of increase from 1912 to 1922 North Carolina shows 175.7 per cent. The entire South shows 78.4 per cent and the entire nation shows 72.2 per cent. North Carolina gained about two and one-half times as fast as the entire nation. Have we expanded our capacities, abilities and knowledge at this rate? In our personal work have we kept pace with the state's development?

I could carry this comparison on and on. There is no end to the figures that can be cited to show what this state has done. But my time is limited and the end is drawing near. What is the need of it? You can see what the state has done in development. Every thing that the state has done the individual must do. Every thing that the state has done this association must do. Where the state has increased its educational expenditures over 23 times we must increase our usefulness a like amount. We must keep up with the state in all of our activities so that there never can be the time when the state will have to stand still while the water works man catches up. The state must look ahead to the water works man and not back upon him.

The master plumber has developed from the side line of the roofer and tinner to the present day plumbing contractor. Once in 1880 the plumber was also a tinner. Then he installed the plumbing on the same basis as the gutters. Then plumbing was the exception, whereas today it is the rule. Today the master plumber will contract for the plumbing in such a building as this and will install it under the supervision of a trained plumbing inspector who has rigid laws to govern the installation. In 1880 there were no water works men in North Carolina. Today there are men who have spent the best part of their lives studying and improving the operation of the water works system. Today we take water that is unfit for any use, even that of sprinkling the streets, and treat it and make it fit for drinking purposes. Today we take the river water that flows past our doors and purify it so economically that it is used for all purposes. We fight fire, wash sewers, sprinkle streets, clean storm drains, wash, scour with it and drink it. It is so plentiful and so regular in delivery that when the consumer happens to find the water shut off he seems to think that the heavens are about to fall. Pure water in unlimited quantities is the rule of the day. It must be so. But the future will not take care of itself. We must look ahead to see that the future has no insurmountable obstacles for us. We must see the needs of the state and be ready to meet these needs. Our vision must take in the whole state and not be limited to the narrow confines of one city or town. This Association must be the leader in more questions than the one of water supply. It must look far enough into the future to see that it will have the men ready for the call, when that call comes, and it must also see that it has the water supply ready to be developed to supply that call.

DOES 100 PER CENT METERING OF SMALL TOWN WATER SUPPLIES PAY?[1]

By F. V. Fields[2]

The question in hand could be easily answered if it did not specify small town; with the mass of statistics available as to the consumption of water in metered and unmetered cities, there can be little doubt in the mind of water works men as to the value of 100 per cent metering for cities. If the city exists whose records show that the cost of its water supply has been increased by metering, these records have been well concealed.

There is, between the small town water supply system and that of the city, a certain analogy, which can give the small town a lesson that many cities have learned at great expense. It will be worth while to consider a few of the outstanding features of such lessons. For example take the city of Chicago, an extremely bad example of a partially metered water supply. The consumption of water in Chicago in 1923 was 294 billion gallons; 83 billion gallons were metered; that is, about 30 per cent, which brought in $5,500,000, approximately, while the remaining 70 per cent brought in $3,500,000 approximately. Whereas the consumption per day should be 150 gallons per capita, it is 275, with a peak load of 400. There are many cities that have cut their consumption in half by 100 per cent metering. There are many small towns of today which will grow into cities. By adopting 100 per cent metering as small towns they will save millions of dollars. It is easier to put in 100 per cent metering in the small town than in the city. The political government of Chicago has failed for twenty years to take action on the recommendation of the chief engineer to provide for 100 per cent metering.

But considering the small town as such, will 100 per cent metering pay as an investment? Assuming that it will not and that only wasteful customers and large users will be metered, who shall decide

[1] Presented before the North Carolina Section meeting, November 13, 1924.

[2] Superintendent Water and Light Plant, Mooresville, N. C.

which is the wasteful customer? If meters are installed at the request of the customer, it will be the careful, saving man who will insist on having a meter, so that, unless authority is given to the water department to place a meter on any customer, there is no need for metering whatever. The customer who asks for a meter expects to reduce his own bill.

As an investment a meter must save enough water to pay for depreciation and interest on the investment. The investment will be about $15 per dwelling service. Considering the life of the meter as fifteen to twenty years, the depreciation will be about 6 per cent and for a return of 6 per cent, a total of 12 per cent or $1.80 must be realized each year per meter. The average water rate for North Carolina is 30 cents per 1000 gallons, which calls for a saving of 6000 gallons per meter, only 500 gallons per month. One or two leaky fixtures, a few minutes a day with the hose, letting the water run to prevent freezing, any of these and many other wasteful practices will far exceed the 500 gallons per month needed to insure a return on the meter. Furthermore, the economical water user is not required to pay a proportion of the additional expense entailed by the wasteful habits of his neighbors.

Walter Gill Kirkpatrick

May 8, 1925

Professor Walter Gill Kirkpatrick, of the University of Mississippi, his wife and 21 others, lost their lives when the river boat *M. E. Norman* capsized and sank in the Mississippi River a few miles below Memphis, May 8.

Professor Kirkpatrick was born at Canton, Mississippi, in 1859, graduated from Vanderbilt University in 1886, and obtained his degree in civil engineering the following year. After obtaining his degree he followed municipal and railroad work, becoming a member of the firm of Landreth and Kirkpatrick in 1892. He was later a United States assistant engineer on the Cumberland River system of locks and dams, and filled a vacancy in the chair of engineering at Union College, Schenectady, N. Y. for one year. About 1896 Mr. Kirkpatrick started in private practice as a consulting engineer, locating in Jackson, Mississippi, and specializing in municipal and hydraulic work. He was city engineer of Jackson, and senior member of the firm of Kirkpatrick and Johnson for a few years prior to 1907. Mr. Kirkpatrick designed and supervised the construction of a large amount of municipal work, mostly water-works, sewers and street paving, from 1900 to 1912, when he became city engineer of Birmingham, Alabama. He was later an engineer for the Alabama Power Company, and returned to private practice about 1915, specializing in water-works, sewers and highway work. This was followed by an engagement as city engineer for Monroe, Louisiana, in 1919. He removed to Baltimore in 1922, and was engaged as an assistant engineer in the Filtration Division of the Baltimore Water Department for a short while. In 1923 he became professor of municipal engineering in the University of Mississippi.

Mr. Kirkpatrick spent his life in carrying on strictly engineering work. The thoroughness with which he planned his work, and the efforts he made to aid his assistants in acquiring a greater knowledge of engineering are the outstanding features of his life.

Paul Howes Norcross

May 8, 1925

Paul Howes Norcross was born in Atlanta, Georgia, January 19, 1880, the eldest son of Dr. Virgil C. and Fanny Howes Norcross, and a grandson of Jonathan Norcross, the first mayor of Atlanta and one of its pioneer citizens. He lost his life, with twenty-two others, on May 8, 1925, when the steamer "H. E. Norman," carrying delegates of the American Society of Civil Engineers, sank in the Mississippi River just south of Kohoma Landing.

After his preparatory education in the schools of Atlanta, Mr. Norcross entered the Georgia School of Technology and was graduated, in 1902, with the degree of Textile Engineer. Immediately afterwards, he spent some six months in one of the large southern cotton mills, but did not find this branch of engineering especially attractive to him. He obtained a position with the Carolina Bridge Company, of Burlington, North Carolina, first in the drafting and designing department, but, because of his sales ability, which was even then apparent, he was soon transferred to the contract department and, later, made Special Sales Representative, covering eleven of the southern states. The Carolina Bridge Company was later merged into the Virginia Bridge Company and Mr. Norcross continued with this organization and was most successful in the promotion and sale of a large number of highway and railway bridges throughout the south. In 1905, he accepted a position with the Westinghouse, Church, Kerr Company, in connection with the structural design of the Pennsylvania Station in New York City. After the completion of this work, he became a member of the staff of Herbert C. Keith, Mem. A. S. C. E., Consulting Structural Engineer, on special bridge design for the New York Central Railroad, in the electrified zone between Harmon and the Grand Central Station.

In 1906, Mr. Norcross formed a partnership with Gabriel R. Solomon, Mem. A. S. C. E., under the firm name of Solomon-

Norcross Company, with principal offices in Atlanta, Georgia, and engaged in general consulting practice throughout the south, covering all classes of municipal and hydraulic work. In 1910, a branch office was opened in Watervliet, New York, and Mr. Frank J. Keis, Mem. A. S. C. E., taken into the partnership, under the firm name of Solomon, Norcross & Keis, on northern work. Mr. Solomon retired from the organization, in 1918, upon his being commissioned an officer in the Army, and the firm operated under the name of Norcross & Keis until January 1, 1923, when Mr. Keis retired, Mr. Norcross continuing the Atlanta office, as a consulting engineer, until the time of his death.

Mr. Norcross' engineering activities, during the last few years, were largely concentrated on water supply and filtration work. His firm served more than fifty municipalities on this particular type of work. At the time of his death, he was Consulting Engineer to the City of Atlanta, where the $3,500,000 pumping and filtration plant was nearing completion, and was in charge of the design and supervision of the new $1,300,000 water supply for Spartanburg, South Carolina.

Among the many projects designed and supervised by Mr. Norcross and his partners might be mentioned: Water supplies at Prattville and Talladega, Alabama; DeFuniak Springs, Milton, Haines City and Sebring, Florida; Cartersville, Rome, Jefferson and Madison, Georgia; Amory, Mississippi; Watervliet, New York; Aiken, South Carolina; and Cleveland and Morristown, Tennessee; and special work for the Island of Bermuda, B. W. I; sewage disposal plants at Lexington, Kentucky, and a number of other cities; water power reports for the Broad River Power Company, Alabama Electric Company and Selma Electric Company; and flood control works at Watervliet, New York.

At the outbreak of the World War, Mr. Norcross was appointed Supervising Engineer at Camp Jackson, Columbia, South Carolina and, on the completion of this work, served in a similar capacity at Camp Humphries, Accotink, Virginia. He was later made Acquisition Agent for Camp Benning, Georgia, and purchased some thirty thousand acres of land for the Government. He was then called to Washington and became a member of the Civilian Staff of the Water Supply Branch of the Construction Division of the Army, in charge of Lt. Col. Dabney H. Maury, Mem. A. S. C. E., and while on this work had many assignments in connection with the water supplies

of the camps, cantonments and regular army posts. After the Armistice, Mr. Norcross returned to Atlanta and, with Mr. Keis, continued his consulting practice.

Mr. Norcross' activities outside of his engineering office were numerous and varied. He had unusual social talents, was thoroughly at home in any company, and was an unusually interesting and ready speaker. His keen wit made him sought after on all occasions as a presiding officer and his appropriate remarks greatly enlivened every meeting at which he was present. No one could put a body of men more quickly at their ease, nor break down a formal and heavy reserve more easily than could he.

He was, for many years, active in the Atlanta Rotary Club and served the Club as President. In 1924, he had the unique distinction, for an engineer, of being made President of the Atlanta Chamber of Commerce, having served that organization as Director and chairman of a number of important committees. He was also President of the Georgia Tech. Alumni Association.

Mr. Norcross took a great interest in the activities of the American Society of Civil Engineers and was especially active as a member of the committee for revising the constitution. He entered the Society as an Associate Member, in 1906, was made a full Member in 1918, and was elected Director in 1924. At the time of his death, he was a delegate to the convention of the Mid-Southern Section of the American Society and had just made an appeal to the members assembled on the boat, on behalf of the Society, asking their fullest cooperation for the new chapter then being organized.

Mr. Norcross was a Scottish Rite Mason, a Shriner, and an Elder in the First Presbyterian Church of Atlanta, Georgia.

Mr. Norcross was married, in November, 1907, to Mattie L. Holt, of Graham, North Carolina. Mrs. Norcross died in October, 1920, ane left a daughter, Miss Catherine Holt Norcross, who survives her father and mother.

Few engineers in the United States were better known or had more friends, and the high regard which he held was beautifully evidenced in a Community Memorial Service, held on May 31, 1925, in Atlanta in which he was characterized as:

A Dutiful Son—A Devoted Husband
A Loving Father—A Loyal Friend
A Public-Spirited Citizen
A True Christian

REPORT OF THE FINANCE COMMITTEE FOR THE FISCAL YEAR ENDING DECEMBER 31, 1924

Your finance committee presents the following report on financial operations for the fiscal year ending December 31, 1924.

The books of the Secretary and Treasurer have been audited and found correct. All vouchers have been examined and verified. The details of the financial affairs of the Association as recorded in the books of the Secretary and Treasurer are in accordance with their respective books and operating income is equivalent to expenses.

Your committee has examined and audited the books of the Treasurer and Secretary and found them to be correct and the cash balances to agree. For the reason, however, that there are certain compensating expenses and income such as reprints of authors' papers, binding cases, etc., reporting initial outlays which later are returned, reports of Secretary and the Treasurer do not exactly agree, though both are correct.

Your committee has taken the figures as submitted by the Secretary, eliminating the compensating receipts and expenses for use in this report. The finance committee by direction of the executive committee recommended at the New York convention last year a budget calling for the expenditure of $30,000.00, which was approved by the convention. This budget was an increase of $8084.73 over the actual disbursements of the fiscal year 1923 and 1924. The actual disbursements as shown by the Secretary's report for the nine month period ending December 31, 1924, were $20,491.38 while the operating income as shown by the same report was $22,558.35, making a net profit from operations $2066.97.

At the beginning of the last fiscal year April 1, 1924, cash balance on hand was $4202.04 and the cash balance at the close of the year $5886.04 or an increase of $1684.00.

The apparent difference between the profit from operations $2066.97 and the increase in the cash balance is covered by investments in authors' copies, binding cases and specifications which will eventually be disposed of.

Owing to the action of the executive committee of the American Water Works Association meeting in New York in May, 1924, at

which time the fiscal year of the Association was changed from April 1–March 31 to January 1–December 31, it was necessary for your finance committee to present a tentative report and a proposed budget to them at their meeting held in New York January 20 to 21, 1925, copy of which follows:

REPORT OF FINANCE COMMITTEE RECOMMENDING PROPOSED BUDGET FOR THE FISCAL YEAR ENDING DECEMBER 31, 1925

In view of the action of the executive committee of the American Water Works Assn. at the New York meeting in May 1924 changing the fiscal year from April 1—March 31 to January 1—December 31, it is necessary for your finance committee to present a proposed budget for fiscal year ending December 31, 1925.

At the last convention a budget of $30,000.00 was provided for the operation of the Association for the fiscal year ending March 31, 1925. Against this there was estimated an income of $26,800.00 and there was cash surplus as of April 1, 1924 of $4,202.04 giving us available resources of $31,002.04 for the year.

From the operation of the association for the past eight months it appears that the budget of $30,000.00 is ample for running the Association with its present activities, the total expenditures for the past eight months being $18,331.90 or less than two-thirds of the budget. This figure is somewhat distorted, however, because during the eight months but six numbers of the JOURNAL have been published whereas in the next four months the JOURNAL will appear monthly. However, since the decision to publish ten numbers of the JOURNAL per year the size has been somewhat reduced with the result that the cost per number is less.

Section expenses have also been considerably less for the past eight months than they will average during the winter months. Notwithstanding however the possibility that the increases in these two items will be greater than the pro rata increase would indicate, your committee believes that the total expenditures for the twelve months from April 1, 1924 to March 31, 1925 would have come well within the $30,000.00.

Your committee therefore feels that it is justified in recommending the same budget as was recommended in May, 1924, for the year January 1, 1925, to December 31, 1925, with an increase of $1,000 for printing the JOURNAL.

1. Convention expenses	$1,400.00
2. Office expense	1,750.00
3. Committee expense	2,550.00
4. Section expense	2,000.00
5. Insurance	50.00
6. Office of Secretary	5,500.00
7. Salary of Editor	2,000.00
8. Printing of JOURNAL	14,500.00
9. Contingencies	200.00
10. Rent of Office	1,050.00
	$31,000.00

Your committee has received but one request for appropriation, that of the publication committee which asks for the sum of $14,500.00 which has been allowed.

Available Resources for fiscal year 1925

On December 1, 1924, there was a total membership of 2134, divided as follows:

Active	1,792
Corporate	158
Associate	173
Honorary	11

This is a total increase of 198 in the past eight months against 234 for the fiscal year 1923–1924.

The executive board at this meeting approved the above report with the exception that the item "Printing of JOURNAL" was changed from $13,500 to read $14,500.

Based on the above membership and the receipts from advertising, subscriptions, sale of JOURNAL, etc. for the past eight months the income would be as follows:

From the annual dues present membership	$16,719.00
Estimate initiation fees and dues from new members	2,400.00
Subscriptions and advertising	9,000.00
Interest on investment	750.00
Sales of JOURNAL and Miscellaneous	1,000.00
	$29,869.00
Estimated cash surplus December 31	$5,500.00

Your committee believes that this is a conservative estimate of income and while the budget is $1,131.00 greater than the direct income it must be remembered that the cash surplus available on December 31 has resulted from balances remaining from unused appropriations for the past four years and it is right that it should be used to overcome deficits in operating expenses while the Association is securing larger membership. An increase in membership of 300 in the next year would overcome any apparent deficit in operating revenues.

Summarizing statement of accounts for fiscal year ending December 31, 1925

Balance on hand in bank April 1, 1924	4,202.94
Net income from all sources	23,396.32
Total operating expenses	21,812.32
Balance on hand	5,886.04
Permanent investment fund of the Association is as follows:	
4 $1000 Dominion of Canada 5 per cent bonds due April, 1931	4,000.00
1 $1000 United States second Liberty Bonds, 4¼ per cent	1,000.00
2 $1000 United States third Liberty Bonds, 4¼ per cent	2,000.00
2 $1000 United States 4th Liberty Bonds, 4¼ per cent	2,000.00
3 $1000 United States bonds 4¼ per cent due 1953	3,000.00
Total	$12,000.00

Your committee believes that the total investment fund of the Assn. should be maintained at all times at not less than $12,000.

For the information of all concerned we are submitting the following resume covering the full twelve month period ending March 31, 1925, of the financial activities of the Association.

1924, budget, disbursements

ITEMS	BUDGET	EXPENSES TO DECEMBER 31, 1924	EXPENSES TO APRIL 1, 1925	TOTAL 12 MONTHS
Convention	$1,400.00	$1,397.94	$720.43	$2,118.37*
Office	1,750.00	1,437.42	437.83	1,875.25
Committee	2,550.00	2,068.98	1,182.42	3,251.40†
Section Expense	2,000.00	962.84	530.78	1,493.62
Insurance	50.00	30.00		30.00
Office of Secretary	5,500.00	3,803.25	1,448.08	5,251.33
Salary of Editor	2,000.00	1,500.03	499.97	2,000.00
Printing of JOURNAL	13,500.00	8,412.89	4,426.77	12,839.66
Contingencies	200.00	90.53	95.00	185.53
Rent	1,050.00	787.50	350.00	1,137.50
	$30,000.00	$20,491.38	$9,691.28	$30,181.66

* $720.43, expenditures in connection with 1925 convention.

† $1399.20, shown in this account covers charges in connection with proposed water works manual.

The treasurer is under bond for $10,000 and the Secretary for $2000.00 in accordance with the order of the executive council and these bonds are in the custody of this committee.

In view of the increase in membership and the rapidly mounting financial transactions of the Association your committee feels that the present method of keeping the books is inadequate and strongly recommends that a new system be installed by some firm of accountants of recognized standing. Under the present system the books are kept on a cash basis and your committee has no means of ascertaining the accounts due and payable.

Your committee also recommends that no expenses properly chargeable to any other budget shall be chargeable to contingent fund and that all items chargeable to the contingent fund for the fiscal year be listed in the annual report.

Your committee would suggest that a vote of thanks be given to Treasurer W. W. Brush for his efforts in behalf of the Association for the manner in which he has taken care of the financial affairs of the Association during the past years.

Respectfully submitted,

G. N. SCHOONMAKER,
H. P. BOHMANN,
G. C. ANDREWS, *Chairman.*

REPORT OF THE SECRETARY FOR YEAR ENDING DECEMBER 31, 1924

FINANCIAL STATEMENT

(Covering Year Ending December 31, 1924)

Cash on hand January 1, 1924		$4,980.28
Receipts:		
Initiation fees	$2,280.00	
Annual dues	16,250.81	
Advertising	6,444.56	
Interest on investments and deposits	447.76	
Subscriptions to JOURNAL	1,131.14	
Sales of JOURNALS	159.47	
Sales of pipe specifications	299.45	
Binders	134.50	
Reprints	427.43	
Miscellaneous	218.21	27,793.33
		$32,773.61
Disbursements:		
Convention expense	$1,414.44	
Office expense	1,973.72	
Committee expense	2,244.30	
Section expense	1,102.09	
Salary of Editor	1,975.03	
Office of Secretary	4,776.58	
Rent of office	965.00	
Printing of JOURNAL	10,515.60	
Binders	291.35	
Reprints	421.75	
Contingencies	224.40	
Pipe specifications	345.99	
Hydrant and valve specifications	101.04	
Office equipment	484.53	
Miscellaneous	171.75	26,887.57
Cash on hand December 31, 1924		$5.886.04
Cash on hand December 31, 1923		4,980.28
Income over Expenditures for year 1924		$905.76

MEMBERSHIP STATEMENT FOR YEAR ENDING MARCH 31, 1925

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
April 1, 1924	1624	147	157	8	1936
New members in year	307	18	32	1	358
Restored and transferred	15	2	1	2	20
	1946	167	190	11	2314
Losses:					
Deaths	14			3	17
	1932	167	190	8	2297
Resignations, transfers and those dropped	122	5	12		139
March 31, 1925	1810	162	178	8	2158
March 31, 1924	1624	147	157	8	1936
Net gain in year ending March 31, 1925	186	15	21	0	222

REPORT OF THE TREASURER FOR THE YEAR ENDING DECEMBER 31, 1924

I submit herewith my report as Treasurer of the American Water Works Association from March 31, 1924, to, but not including, January 1, 1925.

The change in the fiscal year, from April 1 to January 1, necessitates the report for this year covering only nine months. There have been added the receipts and disbursements for the period from January 1, 1924, to March 31, 1924, so that the receipts for a twelve months' period can be determined and used as a comparison with previous and subsequent years. The period from January 1, 1924, to March 31, 1924, has been selected, rather than the period from January 1, 1925, to March 31, 1925, as in the first three months of this year the Association has collected the greater part of the dues that heretofore would have been paid in April, and the resultant receipts if the 1925 period were used would be greatly in excess of what would represent the present yearly receipts.

The funds of the Association are on deposit with the United States Mortgage and Trust Company at their bank located at 55 Cedar Street, New York City. This bank was selected in 1921 by vote of the Executive Committee.

RECEIPTS AND DISBURSEMENTS, APRIL 1, 1924 TO DECEMBER 31, 1924

Receipts

Balance on hand April 1, 1924	$4,296.73	
Received from Secretary	23,299.69	
Interest on deposits	143.47	
Interest on investments	270.00	
Cancellation of check no. 1409	2.30	
Total		$28,012.19

Disbursements

Expended in payment of vouchers aggregating 265 in number, and comprising vouchers 1607–1871, both inclusive (Checks bearing the same numbers as the vouchers have been drawn, with the exception of those vouchers which cover charges made by

the bank on check collections, and the amount of these vouchers is set forth separately below)	$21,397.60	
Exchange on check as charged by bank, including charge of 30¢ for December, 1924, for which no voucher has been drawn	18.50	
Deduction for seven checks returned by bank for various reasons	73.50	
Total		21,489.60
Balance, January 1, 1925		$6,522.59

Cash balance at close of business December 31, 1924, as shown by the December statement of the U. S. Mortgage & Trust Co.		$6,580.04	
From this balance there should be deducted for unreturned checks the following:			
No. 1448	$.18		
No. 1512	1.57		
No. 1546	3.96		
No. 1578	1.74		
No. 1871	50.00		
Total		57.45	
Net bank balance			$6,522.59
Receipts from January 1, 1924, to March 31, 1924		$4,383.45	
Disbursements from January 1, 1924, to March 31, 1924		5,651.78	

The receipt for interest on investments does not include $270.00 which became due at various dates towards the end of the year, these coupons having been deposited on February 2, 1925.

The receipted vouchers have been returned to the secretary. The cancelled checks and deposit slips, with the book of the treasurer, are available for audit.

The permanent fund has not been changed during the year, and consists of the following bonds, which are in a safe deposit box at the United States Safe Deposit Company, 32 Liberty Street, New York City.

4—$1000 Dominion of Canada 5%	$4,000
1—$1000 U. S. Liberty 2d 4¼%	1,000
2—$1000 U. S. Liberty 3d 4¼%	2,000
2—$1000 U. S. Liberty 4th 4¼%	2,000
3—$1000 U. S. Treasury 4¼%	3,000
Par value of permanent fund	$12,000
Interest on permanent fund	$540

The treasurer received no salary, and is under $10,000 bond which has been placed by the Finance Committee.

W. W. BRUSH,
Treasurer.

ANNUAL REPORT OF THE TREASURER OF THE ELECTROLYSIS FUND

March 30, 1925.

I submit herewith my report as Treasurer of the American Water Works Association from March 31, 1924, to, but not including, January 1, 1925.

The electrolysis funds are on deposit with the United States Mortgage and Trust Company at their bank located at 55 Cedar Street, New York.

RECEIPTS AND DISBURSEMENTS, APRIL 1, 1924, TO DECEMBER 31, 1924

Receipts

Balance on hand April 1, 1924	$1,324.13	
Interest on deposits	19.53	
Total		$1,343.66

Disbursements

Payment to Albert F. Ganz, Inc. (Check No. 19)	$64.95	
Total		64.95
Balance, January 1, 1925		$1,278.71

W. W. BRUSH,
Treasurer.

SOCIETY AFFAIRS

ILLINOIS SECTION

The seventeenth annual meeting in the Illinois section was held at the Orrington Hotel, Evanston, Ill., on March 17 and 18, 1925. This meeting was held with the Iowa and Wisconsin sections and the first session, on Tuesday morning, was a joint meeting with the second annual conference of Water Treatment Plant Operators of Illinois. The total number registered was 96. This number does not include many guests at the annual dinner and several persons who attended other sessions but failed to register. Of those registered, 33 were active members of the Illinois section, 5 were representatives of 3 corporate memberships of the Illinois section and 3 represented 3 associate members of the Illinois section. One active member present was from a corporation holding membership not listed above and one active member present is connected with afirm which holds associate membership. The number of active members registered from other states was 4 from Iowa, 2 from Wisconsin, 2 from Indiana, 1 from Missouri, and 1 from Virginia. Fifteen persons present represented 11 associate memberships from states other than Illinois.

Mr. F. C. Jordan, President of the Association was unable to be present on account of the work involved in preparing for the national meeting at Louisville. C. R. Knowles was represented by J. P. Hanley. Joel Connolly of Chicago, District Engineer of the United States Public Health Service, gave a very interesting illustrated talk at the evening session. Many views taken by Mr. Connolly in Egypt, Mesapotamia and other places, including many of especial interest to persons concerned with water supplies, were shown. Otherwise the program was as noted below:

TUESDAY, MARCH 17

9:30 A.M.

Joint meeting with the Second Annual Conference of Water Treatment Plant Operators of Illinois. Round table discussions on operation of water purification.

1:30 P.M.

Address of Welcome. H. P. Pearsons, Mayor, City of Evanston.
Response. A. M. Buswell, Chairman, Illinois Section.
Report of the Secretary. G. C. Habermeyer.
Report of the Treasurer. H. E. Keeler.
The Evanston Filter Plant. Paul Hansen, Consulting Engineer, Chicago.
The Orlando, Florida, Municipal Water and Light Plant. W. W. Matthews, Assistant Engineer Alvord, Burdick and Howson.
The Diesel Engine and Municipal Water Works. R. V. Cook, Manager of Pump Dept., Fairbanks, Morse & Co.
Practical Considerations in the Water Supply Development for Small Cities. C. M. Ladd, Chicago Bridge & Iron Works.

6:30 P.M., ANNUAL DINNER

Election of Officers.
Address. F. C. Jordan, President of American Water Works Association.
The Des Moines Municipal Water Works. Film.
Greetings from representatives of organizations.

WEDNESDAY, MARCH 18

9:30 A.M.

Rapid Methods of Boiler Water Analysis.[1] R. C. Bardwell, Supt. Water Supply, Chesapeake & Ohio Railroad.
Discussion by C. R. Knowles, Supt. Water Service, Illinois Central Railroad.
Discussion by A. M. Buswell, Chief, State Water Survey Division.
The New Hinsdale Water Softening Plant. Charles P. Hoover, Chemist, Filtration Plant, Columbus, Ohio.
The Springfield, Illinois, Filtration and Softening Plant. C. S. Timanus, Asst. Engineer, Burns & McDonnell.
Water Supplies for Domestic Animals. Jack J. Hinman, Jr., Chief, Water Laboratory, State Board of Health, Iowa.

1:30 P.M.

Meters and Their Effect on the Evansville Water Works. Charles Streithof, General Manager, Evansville, Ind., Water Works.
Storage, A Solution of the Fire Reserve Problem.[2] C. W. Parsons, Engineer, Illinois Inspection Bureau.
Discussion of Water Works Problems (leaders of discussion to be announced):

1. How do you check accuracy of meters and of what do meter records consist?
2. How much of your total pumpage is sold and what becomes of the balance?
3. What use have you made of trenching machinery, air hammers, air drills and other mechanical equipment?
4. What has been your experience with joint material?

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[1] This Journal, page 107.
[2] Journal, June, 1925, page 638.

5. Are you troubled with electrolysis?
6. What becomes of the depreciation reserve?
7. What is the most equitable method of collecting for fire service?

The principal discussions were on metering and accuracy of meters, joint material, and depreciation reserve.

The following officers were elected for the coming year: Chairman, L. R. Howson; Vice Chairman, W. R. Gelston; Treasurer, H. E. Keeler; Trustee, H. M. Ely.

An invitation from the City of Springfield and the Chamber of Commerce of Springfield to hold the next meeting at the city of Springfield, was read by H. F. Ferguson.

At the close of the meeting the executive Committee appointed G. C. Habermeyer, Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Pulverized Fuel. DAVID BROWNLIE. Electrician, **91**: 690–1, 1923. From Chem. Abst., **18**: 576, February 20, 1924. Brief discussion of installations for steam generation at Lakeside, Milwaukee, and River Rouge, Dearborn, Mich., and comparison with "Lopulco" system. Boiler-house efficiencies of 85–86 per cent are secured with latter, chimney losses being 8 per cent, unburnt carbon in ash 0.5 per cent, an excess air for combustion 10.5–25 per cent overt theoretical. Also in Iron Coal Trades Rev., **107**: 889–90, 924–6, 1923.—*R. E. Thompson.*

Pulverized Fuel for Large Boilers. J. C. HOBBS and L. W. HELLER. Proc. Eng. Soc. Western Penn , **39**: 217–66, 1923. From Chem. Abst., **18**: 576, February 20, 1924. Possibilities of powdered coal discussed. Pulverized fuel is justified from standpoint of increased boiler and stack capacity, increased boiler and combustion efficiency and decreased fuel requirements for banking and maintenance.—*R. E. Thompson.*

The Nature of Goiter in Relation to Iodine Content. H. HOMMA. Mitt. Grenzg. Med. Chir., **36**: 389–92, 1923. From Chem. Abst., **18**: 550, February 20, 1924. Data on iodine content of thyroid in 30 cases of goiter.—*R. E. Thompson.*

The Pathological Physiology of Goiter. Y. HARA. Mitt. Grenzg. Med. Chir., **36**: 527–57, 1923. From Chem. Abst., **18**: 550, February 20, 1924.—*R. E. Thompson.*

Investigations of Radioactive Springs. AUG. BECKER. Z. anorg. allgem. Chem., **131**: 209–35, 1923. From Chem. Abst., **18**: 619, March 10, 1924. Data on Ra and Rn contents of waters, sediments, and dissolved gases of springs at Heidelberg, Dürkheim, and Brambach.—*R. E. Thompson.*

The Radioactivity of Algerian Mineral Springs. I. POUGET and D. CHOUCHAK. Compt. rend., **177**: 1112–4, 1923. From Chem. Abst., **18**: 621, March 10, 1924. Comprehensive survey, in which springs are classed according to chemical character. Radioactive springs are often found in oldest rocks, usually near intrusions of pegmatite, etc. Radioactivity in more recent

formations is only found where spring comes up through fault or fracture near eruptive intrusions.—*R. E. Thompson.*

Chemical Analysis of Three Algerian Radioactive Springs. I. POUGET and D. CHOUCHAK. Compt. rend., **177**: 1319–21, 1923. From Chem. Abst., **18**: 621, March 10, 1924. Best of these has radioactivity of 5.3 millimicrocuries and contains only 0.93 p.p.m. solids.—*R. E. Thompson.*

Chemical Examination of Samples of Water and of Shells from the Inle Valley. G. J. FOWLER, M. A. MALANDKAR and N. ANNANDALE. J. Ind. Inst. Sci., **6**: 185–94, 1923 From Chem. Abst., **18**: 715, March 10, 1924. Analyses given which were made to determine whether relation exists between mineral content of water and characteristics of lake fauna. Assumed connection between magnesium content of water and of shells was disproved.—*R. E. Thompson.*

The Effect of 0.9 per cent Sodium Chloride on Various Bacteria. A. DUTHOIT. Compt. rend. soc. biol., **89**: 548–50, 1923. From Chem. Abst., **18**: 544, February 20, 1924. Bacterial emulsion containing 5–20 million organisms per cubic centimeter was added to 5 cc. 0.9 per cent salt and drop of mixture removed from time to time, diluted with 10 cc. salt solution, and incubated in gelose medium. Plates were then made and a number of colonies counted. With B. coli, number was reduced 50 per cent after 6 hours, greatest decrease occurring in first hour. **Effect on Different Bacteria of Sodium Chloride Solutions of Various Concentrations.** Ibid., 550–2. Each organism has an optimum salt concentration in which it survives for longest time. For typhoid bacillus, this concentration is between 1 and 2 per cent, and for B. coli and Paratyphoid B between 2 and 3 per cent. **Effect on Bacteria of Sodium Chloride in Conjunction with Other Salts.** Ibid., 553–4. Sterilization with pure sodium chloride solution is practically complete in approximately 7 hours; but when calcium chloride is added, time required is lengthened to 12–48 hours, while in Ringer's solution, survival may almost be indefinite.—*R. E. Thompson.*

Boiler Troubles from Poor Feedwater. J. E. STILLWELL. Oil and Gas J., **22**: 80, 126–9, 1923. From Chem. Abst., **18**: 561, Feb. 20, 1924. General discussion of priming and foaming, corrosion, scale-formation, and softening. —*R. E. Thompson.*

Titrimetric Determination of Aluminum. ALFRED WOHLK. Arch. Pharm. Chem., **30**: 302–6, 320–6, 1923. From Chem. Abst., **18**: 510, February 20, 1924. Titrimetric method of Valentin (C. A. **6**: 2974) is critically examined and more satisfactory method described, depending on reaction: $AlCl_3 + 3NaOH = Al(OH)_3 + 3NaCl$. Treat 10 cc. of sample with 10 cc. of solution of 12 g. sulfuric acid and 6.5 g. potassium sulfate in 100 cc. water to convert aluminum into aluminum sulfate and add 100 cc. of 90 per cent alcohol in small portions with constant stirring; alum is precipitated quantitatively as fine crystals. Filter, wash 3 times with 20 cc. 70 per cent alcohol, transfer most of crystals to 300 cc. dish and wash remainder through paper with hot water,

testing washings with litmus paper. Add 4 g. $BaCl_2 \cdot 2H_2O$ dissolved in 20 cc. of water and titrate with carbonate-free sodium hydroxide to distinct red with phenolphthalein. Dilute to 200 cc., heat over free flame to hydrolyze last traces of aluminum chloride, and restore color with few drops of sodium hydroxide. Barium sulfate need not be removed and barium chloride (or calcium chloride) does not interfere. Error is of order of 0.01 per cent. Methods is applicable in presence of small amounts of iron, e.g., when aluminum : iron ratio is 100:4.—*R. E. Thompson.*

The Determination of Nitrites in Water with Neutral Red. H. Stoof and M. Horn. Wasser u. Gas. **14**: 175–7, 1924. From Chem. Abst., **18**: 873, March 20, 1924. Reaction involved, depending on formation of blue coloration, was studied in various acid solutions. Hydrochloric acid proved unsatisfactory, owing to high speed of reaction and intense coloration. Sulphuric acid gave excess errors and could not be used in presence of nitrates. Reaction did not occur in acetic acid. Phosphoric acid proved satisfactory under all conditions. Method may be used to detect as low as 0.2 mg./l. N_2O_3, recommended procedure being to add to 10 cc. of water 2 cc. of 0.002 per cent neutral red (aqueous) and 4 cc. of 25 per cent phosphoric acid. Presence of ferrous, ferric, or manganese salts, or of organic matter, does not interfere in either sulphuric or phosphoric acid solution.—*R. E. Thompson.*

Effect of Temperature on Bacterial Removal With Chlorine Gas. Hilger and L. Tietz. Gesundh. Ing., **46**: 329–30, 1923. From Chem. Abst., **18**: 873, March 20, 1924. Temperature variations have little influence on chlorine dosage required for Königsberg supply. Variations in dosage are due to fluctuations in organic content.—*R. E. Thompson.*

The Purification of Water Supplies With Special Reference to Shanghai. C. D. Pearson. Far Eastern Rev., **19**: 178–83, 1923. From Chem. Abst., **18**: 873–4, March 20, 1924. Natural purification of rivers in China appears to be due to large amount of silt present. Artificial assistance to process, analogous to activated sludge process, suggested.—*R. E. Thompson.*

Water In the Paper Industry. M. Aribert. Science et industrie, **7**: 108, 51–4, 1923. From Chem. Abst., **18**: 903, March 20, 1924. Outline of consumption in manufacture of various grades of pulp and paper, with discussion of qualities required and of effects of dissolved salts.—*R. E. Thompson.*

Internal Treatment of Boiler Waters. A. S. Harvey. Ind. Eng. Chem., **16**: 206, 1924. From Chem. Abst., **18**: 873, March 20, 1924. Laboratory experiments are of little value in predicting value of boiler compound. Continued large sales of graphite for boiler treatment prove this material to be harmless and of value.—*R. E. Thompson.*

Rebuilding the Trickling Filters of the "Old-Berlin" Waterworks. O. Sperling. Technisches Gemeindeblatt, **16**: 139–40, 1923; Gesundh. Ing., **47**: 27, 1924. From Chem. Abst., **18**: 874, March 20, 1924. Description given.

Plant removes approximately 90 per cent of iron from 80,000 cubic meters per day of water containing 1.2–2 p.p.m.—*R. E. Thompson.*

Waterworks Calculations for Large Cities. H. PETER. Gas u. Wasserfach, **98**: 698, 1923. From Chem. Abst., **18**: 874, March 20, 1924. Formulas and average figures given for estimation of demand, increase in population, loss of head, and coefficients of friction of various pipes.—*R. E. Thompson.*

The Filtration, Chlorination, and Re-Use of Swimming-Pool Waters. B. BÜRGER. Veröffentl. deutsch. Ges. f. Volksbäder, **7**: 12–17, 1922; Gas u. Wasserfach, **66**: 515–16, 1923. From Chem. Abst., **18**: 874, March 20, 1924. Chlorination and rapid filtration has increased period of use of water in Hallen pool, Berlin, from 2–3 days to 3–4 weeks. Overdose of 0.5 p.p.m. chlorine has resulted in freeing water of pathogenic bacteria, giving bacteria-free water in 5 out of 11 trials and nearly complete removal in remainder. In no case were B. coli present.—*R. E. Thompson.*

The Precipitation of Aluminium as Hydrated Oxide by Means of Ammonia. G. JANDER and B. WEBER. Z. anorg. allgem. Chem., **131**: 266–74, 1923. From Chem. Abst., **18**: 799, March 20, 1924. Series of experiments with pure aluminium solutions showed that in spite of careful precipitation with ammonia, about 3 mg. of aluminium, or 1 per cent of total present, escaped precipitation, and was recovered in filtrate.—*R. E. Thompson.*

The Quantitative Determination and Separation of Aluminium. G. JANDER and B. WEBER. Z. angew. Chem., **36**: 586–90, 1923; cf. C. A., **16**: 2461. From Chem. Abst., **18**: 799, March 20, 1924. Cf. this JOURNAL), **11**: 4, 935. Modification of procedure and apparatus previously recommended.—*R. E. Thompson.*

Determining Discharge Coefficients for Flow of Water in Short Pipes. O. W. BOSTON. Chem. Met. Eng., **30**: 56–9, 1924. From Chem. Abst., **18**: 871, March 20, 1924. Methods and results given.—*R. E. Thompson.*

The Hydrogen-Ion Concentration of a Creek, Its Waterfall, Swamps, and Ponds. R. P. COWLES and A. M. SCHWITALLA. Ecology, **4**: 402–16, 1923. From Chem. Abst., **18**: 872–3, March 20, 1924. Effect of active flow on pH of water was determined. In ponds, pH is modified by aquatic fauna and flora; but under certain conditions may be practically constant. Flowing slowly over decaying vegetable matter lowers pH. Rapid flow over clean bed increases pH, particularly at falls and rapids, probably due to aëration. These variations may be correlated with free carbon dioxide content. Stagnation and low but uniform pH appear to be two factors which determine distribution of *Euglena.*—*R. E. Thompson.*

Practical Biology, and Means of Destroying the Migratory Mussel (Dreissenia Polymorpha) in Waterworks. D. G. WILHELMI. Deut. Wasserwirtschaft, **18**: 107, 1923; Gesundh. Ing., **47**: 4, 1924. From Chem. Abst., **18**: 874, March

20, 1924. Migratory mussel requires solid surroundings for growth; purity of surrounding water seemingly has little effect on it. It is found in water requiring a minimum of 40–50 mg./l. potassium permanganate [corresponding to 10–12.5 p.p.m. oxygen consumed—ABSTR.], and containing certain organisms, certain lime content is advantageous, while even very low iron content is deleterious. Deficiency of oxygen can be withstood for a time only, as can also sharp variations in temperature. Influence of light has not been determined. Active migration occurs only when food is required. Multiplication is prevented by (*a*) artificial lowering of oxygen content, (*b*) increasing salt content of water to 1 per cent or more, (*c*) removal of water from, and not using the infested waterway, and (*d*) use of chlorine; last being considered most practical.—*R. E. Thompson.*

Boiler Efficiency. C. E. COBURN. Blast Furnace and Steel Plant, **12**: 75–6, 1924. From Chem. Abst., **18**: 894, March 20, 1924. Relation of carbon dioxide to pit losses must be carefully observed. Several large power plants have tried and abandoned bonus systems based on carbon dioxide content of flue gas, owing to increased ash pit losses. Excess air should be reduced by maintaining more even fuel bed, particularly at that part of grate where fuel is near point of discharge. Advisable carbon dioxide value depends on ability of stoker operators, as there is a value which, if exceeded, reduced efficiency will result. Chart given which can be used to determine boiler efficiency from boiler losses.—*R. E. Thompson.*

Richmond puts Shockoe Creek Into a Concrete Conduit. ALLEN J. SAVILLE. Eng. News Rec., **93**: 900–2, 1924. Construction of conduit, to prevent flooding, described. Cost of concrete, including cement and forms was $13.41 per cubic yard.—*R. E. Thompson.*

Duplicate Steel Pipelines from Bombay. Eng. News Rec., **93**: 905, 1924. Duplicate riveted steel water mains, 55 miles in length, are being constructed from Lake Tansa, to provide additional 108 Imperial m.g.d. to Bombay supply. Present consumption is 58 Imperial m.g.d.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Autographic Hydraulic Volume Gage. Eng. News Rec., **93**: 913, 1924. Instrument for producing autographic records of hydraulic quantities which depend on water stage described, consisting of stiff spring from which is suspended heavy plunger which dips into water to be gaged. Buoyancy of plunger varies according to immersed volume and movement of pen attached can be made proportional to any desired function of water stage by varying shape of plunger.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Quake Damage to Water Supplies of Japanese Railways. M. NAWA. Eng. News Rec., **93**: 986, 1924. Of 96 wells in district, 26 were affected by shock; but damage was very small compared with that to structures above ground or just below ground surface, such as pipes.—*R. E. Thompson.*

Tree Growth Encroaches on Reservoir. F. W. MAGER. Eng. News Rec., 93: 962, 1924. Krian irrigation reservoir, Perak, Br. Malaya, reduced 20 per cent in 11 years by tree growth. Area was originally covered by dense forest and was not cleared. All stumps of original trees were standing, up to water level, when reservoir was dry in 1922 due to drought, after 16 years service. Work of clearing is being proceeded with.—*R. E. Thompson.*

Making House Service Connections to Mains. W. W. MONK. Eng. News Rec., 93: 1046, 1924. Simple method, which may be known as "expanded metal joint," described.—*R. E. Thompson.*

Discharge of Irrigation Syphons in California. L. STANDISH HALL. Eng. News Rec., 93: 1024–5, 1924. Tests of syphons showing higher friction losses than is usual for asphalt-coated riveted steel pipe.—*R. E. Thompson.*

Repairing the Laguna Dam on the Colorado. R. M. PRIEST. Eng. News Rec., 93: 1002–3, 1924. Repairs, which comprise only maintenance on dam after 15 years service, described. Cost was equivalent to 0.4 per cent of original cost per year.—*R. E. Thompson.*

Early Results from Memphis Water Purification Plant. WELLINGTON DONALDSON. Eng. News Rec., 93: 992–4, 1924. New supply is drawn from 21 new 12-inch wells and one 10-inch well, air-lift pumping being employed. Purification process consists of aëration and rapid sand filtration. Approximately 73 per cent of 120 p.p.m. CO_2 estimated to be present is removed by air-lift, and H_2S practically eliminated. It has been found that removal depends on air-to-water ratio of air-lift, CO_2 content of pumped water being fair index of pumping efficiency. Filter effluent contains 7–8 p.p.m. CO_2. Iron in solution is oxidized by air-lift and deposited on any surface in contact with water, particularly on coke surface in aërator, removal being completed by filters, final effluent containing 0.01–0.03 p.p.m. Formerly water from one source contained 1.8 p.p.m. Fe, and, due to corrosion by CO_2, tap water not uncommonly contained as high as 5 p.p.m.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Filter Loading Studies on Ohio River. H. W. STREETER. Eng. News Rec., 93: 962, 1924. Ohio River is most highly polluted at Ironton, average B. coli index being 14,900 per 100 cc. Wide variations in bacterial content were noted. Average bacterial reduction by ten plants studied, with and without chlorination respectively, were: 37° count 95.9 and 99.8 per cent; B. coli index 99.6 and 99.98 per cent. Percentage reductions in 37° count by different stages in purification process were: primary sedimentation 73.4, coagulation and secondary sedimentation 74.4, filtration 85.3, chlorination 89.7. The percentage removals increase with increasing content of influent at diminishing rate, becoming asymptotic to fairly well defined maximum value, which appears to represent upper limit of efficiency obtainable. Studies indicate that majority of plants, with aid of chlorination, can produce effluents which comply with Treasury standard, but that limit of pollution which can be dealt with by

processes at present available has been reached in Ohio River. Of 9 plants, 5 reported yearly average B. coli index greater than 2 per 100 cc. in unchlorinated filter effluent, and 7, greater than 1 per 100 cc. Advantage of double over single coagulation and of double over single sedimentation was clearly shown by survey.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Forty-Second Annual Report of the Provincial Board of Health of Ontario, Canada, for the Year 1923. 461 pp. **Report of the Provincial Sanitary Engineer.** F. A. DALLYN. Ibid., 54 75. Policy of maintaining residual chlorine content of 0.2 p.p.m. in chlorinated water throughout province has been adopted and found most effective in improving quality of water supplied. Regulations governing swimming pools, approved December 17, 1923, include following: (1) Water must not be heated to temperature above 72°F., and air temperature must not be more than 8° warmer, or 2° cooler, than water temperature. It is recommended that air temperature be maintained at 5° above pool temperature. (2) Number of bathers during any 24 hr. interval must not exceed 20 per 1000 gallons of clean water added to pool during that period, and at no time shall the number exceed 3 per 1000 gallons total capacity. (3) Water at all times shall be sufficiently clear to permit black disc 6 inches in diameter on white field, when placed at bottom of pool at deepest point, to be clearly visible from side-walks of pool at distances up to 10 yards, measured from line across pool through said disc. (4) There shall be maintained in water of all pools residual free chlorine content of not more than 0.5 and not less than 0.2 p.p.m. (5) When alum is used in purification, water must be alkaline to methyl red. **A Comparison of the Differential Media Used in the Isolation of B. Coli in Water Analysis.** H. E. P. VALE. Ibid., 89–92. Lactose broth, lactose bile broth and safranin broth were compared as preliminary enrichment media, colon group being detected in greatest dilution (sewage) according to following percentages: lactose broth 57; lactose bile broth 1.3; safranin broth 0; lactose broth and bile broth 30; positive all three 12. B. coli could be isolated from 79 per cent of tubes showing less than 10 per cent of gas in 48 hrs. Eosin methylene blue agar is considered most suitable confirmatory medium because of (1) ease of preparation, (2) permanence, and (3) constancy of composition. Difficulties in use of litmus lactose agar may be overcome by adjusting pH to 7.2 before sterilization and substituting 1 per cent Andrade indicator for litmus. Possibility of inversion of lactose is less when sterilization is carried out in autoclave at 15 pounds for 15 minutes, than by fractional method on 3 successive days in Arnold sterilizer. **The Protection of Wells Used as a Source of Domestic Water Supply.** Ibid., 147–50. Most suitable well top is that of concrete, well sloped and provided with gutter. Lining should be watertight to depth of 10 feet, and excavated material rammed back in place to provide filtering medium. Majority of pathogenic organisms whose natural habitat is human body do not survive in soil longer than 10 days to 2 weeks, therefore location of well should be such that infective material is retained in soil for this length of time before gaining access to well. **Study of Pretreatment of Thames River Water at Chatham.** A. V. DELAPORTE and G. A. H. BURN. Ibid., 151–68. Supply is drawn from Thames River and is purified by storage (3 days), filtration through horizontal pressure filters,

and chlorination before and after filtration, a residual of 0.2 p.p.m. after 15 minute contact being maintained in filtered water. To produce filter effluent with turbidity of less than 10 it has been found necessary that influent be less than 75 and preferably less than 50. This required alum dosage of 5 g.p.g. Storage alone produced a degree of turbidity removal which decreased almost to zero when turbidity was 200 or less. Optimum pH for filtration was found to be 6.8–7.0.—*R. E. Thompson.*

First Annual Report, Provincial Bureau of Health, Quebec, Canada, 1922–3. 416 pp. Excluding epidemic at Masonville, caused by discharges of typhoid patient gaining access to town's water supply, typhoid statistics are considered remarkably favorable. **Report of the Division of Laboratories.** Ibid., 129–33. A. BERNIER and McH. MCCRADY. Analyses made are summarized and pertinent data re milk examinations tabulated. **Report of the Division of Sanitary Engineering.** Ibid., 135–55. Application of Public Health Act has resulted in construction of several filtration plants and installation of chlorination apparatus in number of towns. Number of municipalities now supplied with filtered river water is 29 and with chlorinated water 15. Water purification has reduced typhoid rate in province from 30 in 1910 to 12 in 1922.—*R. E. Thompson.*

Occurrence of Sulfate-Reduction in the Deep Layers of the Earth. C. A. H. VON WOLZOGEN KÜHR. Proc. Royal Acad. Amsterdam, **25**: 188–98, 1922. From Chem. Abst., **17**: 47, January 10, 1923. Sulfate-reduction, indicated by color due to formation of ferrous sulfide, was noted in medium (water 1000, sodium lactate 5, asparagine 1, $MgSO_4 \cdot 7H_2O$ 0.5, $FeSO \cdot 7H_2O$ 0.01 g. in 150 cc.) to which had been added 5–10 g. of soil from cores of 9 wells along the Sprenkelkanaal. Anaërobic cultures yielded much larger total of bacteria than aërobic. Majority of bacteria derived from aërobic and anaërobic cultures were facultative anaërobes. Spores were not formed. Conditions for sulfate-reduction by *Microspira desulfuricans* are absence of oxygen and presence of organic compounds, sulfates, and required mineral compounds.—*R. E. Thompson.*

Decomposition of Kaolin by Organisms. W. J. VERNADSKY. Compt. rend., **175**: 450–2, 1922. From Chem. Abst., **17**: 124, January 10, 1923. Murray and Irvine (Proc. Roy. Soc. Edinburgh, **'8**: 245, 1891) showed that sea water did not contain sufficient silica to maintain diatoms. Murray found that *Navicula* could flourish in water in which silica was absent but clay present, and suggested that diatoms could decompose clay and utilize silica thus liberated. Vernadsky found that *Nitzschia* developed readily in colloidal clay to which nutritive substances had been added. Free aluminum hydroxide was produced in these cultures. Cultures were made in glass vessels coated with paraffin.—*R. E. Thompson.*

Technic of the Use of Liquid Chlorine. HENRI BARTHÉLÉMY. Rev. prod. chim., **25**: 649–52, 1922. From Chem. Abst., **17**: 184, January 10, 1923. Description of equipment required for obtaining constant flow of chlorine from cylinders and drums.—*R. E. Thompson.*

Electrical Carbon Dioxide Recorders. G. A. SHAKESPEAR. Electrician **89**: 543, 1922. From Chem. Abst., **17**: 2, January 10, 1923. Electrical recorder, actuated by thermal conductivity, which varies with emposition, described. —*R. E. Thompson.*

Iron Bacteria as Inorgoxidants. S. WINOGRADSKY. Centr. Bakt. Parasitenk., II Abt. **57**: 1–21, 1922. From Chem. Abst., **17**: 120, January 10, 1923. Iron bacteria belong to that class known as inorgoxidants, deriving all their energy from oxidation of inorganic substances and possessing little or no ability to attack organic substances. Carbon dioxide is source of carbon.—*R. E. Thompson.*

Recent Advances in the Bacteriological Examination of Water. W. J. WILSON. J. State Med., **30**: 437–43, 1922; Pub. Health Eng. Absts., (November 11, 1922). From Chem. Abst., **17**: 164, January 10, 1923. Classification by means of methyl red, Voges-Proskauer, and Koser's uric acid tests is recommended in addition to quantitative determination of B. Coli.—*R. E. Thompson.*

Estimation of Chloride Hardness in Water. H. BECKURTS. Z. angew. Chem., **35**: 434–5, 1922. From Chem. Abst., **17**: 164, January 10, 1923. General discussion of determination of magnesium chloride. Determination of magnesium is bothersome so that of chlorine is favored. Method of Bosshardt and Burawzow, as used by Fricke, was found most satisfactory. Five hundred cubic centimeters of sample are evaporated to dryness, residue extracted with alcohol-ether solution (equal parts by volume), and chlorine determined by titration of extract, or calcium and magnesium determined gravimetrically in total mass. Results showed that approximately 99 per cent of magnesium chloride is recovered. Presence of sodium chloride gave a rather constant value corresponding to 5.4 p.p.m. or 0.43 hardness, which should be deducted as correction. Nitrates do not interfere, but presence of ammonium chloride may disturb results.—*R. E. Thompson.*

Electric Cement. ANON. Rev. ing. index tech., **29**: 155–7, 197–8, 1921; France-Belgique, **1**: 71–2, 199–200, 1922. From Chem. Abst., **17**: 195, January 10, 1923. Electric cement is an aluminous cement manufactured in electric furnace. Hydraulic index is generally above 1, and apparent density, with degree of fineness such that 5 per cent remains on sieve of 4900 meshes per square centimeter, is not over 1. It is not decomposed by sulfates of alkalies or alkaline earths or by sea water. With 300 kgm. cement to cubic meter of sand, strength after 48 hours is more than double that of similar mixture of artificial portland cement after 90 days.—*R. E. Thompson.*

NEW BOOKS

L'alimentation de l'agglomeration bruxelloise et de la Basse Belgique en eau potable. Situation actuelle. E. WALIN and A. DEBLON. Ghent: Imp. F. et R. Buyck frères. 90 pp. Fr. 10. From Chem. Abst., **18**: 562, February 20, 1924.—*R. E. Thompson.*

Gas und Wasserversorgung der Gebäude. WILHELM SCHWAB. Berlin and Leipzig: Walter de Gruyter and Co. 1923. Reviewed in Gesundh, Ing., **46**: 221, 1923. From Chem. Abst., **18**: 562, February 20, 1924.—*R. E. Thompson.*